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THE FIRST CROSSING OF THE ALPS IN AN AEROPLANE.

By the Paris Correspondent of SCIENTIFIC AMERICAN.

THE crossing of the Alps in a flying machine, the most perilous sporting venture yet known, was organized to take place from the 18th to the 24th of September, and the contest was open to all air craft.

The departure was to be from the Briguer-Berg (Briegenberger) plateau, 870 meters elevation, and the voyage was to terminate at the aerodrome of Milan, which is 122 meters above the sea. The aviators were required to start at any time between the above-named dates and could make as many stoppages or landings as they desired between the two extreme points, but the trip was to be completed within 24 hours. The one cro[illegible] was to be declared the winner and to receive 70,000 francs, the second was to get 20,000 francs, and the third 10,000 francs.

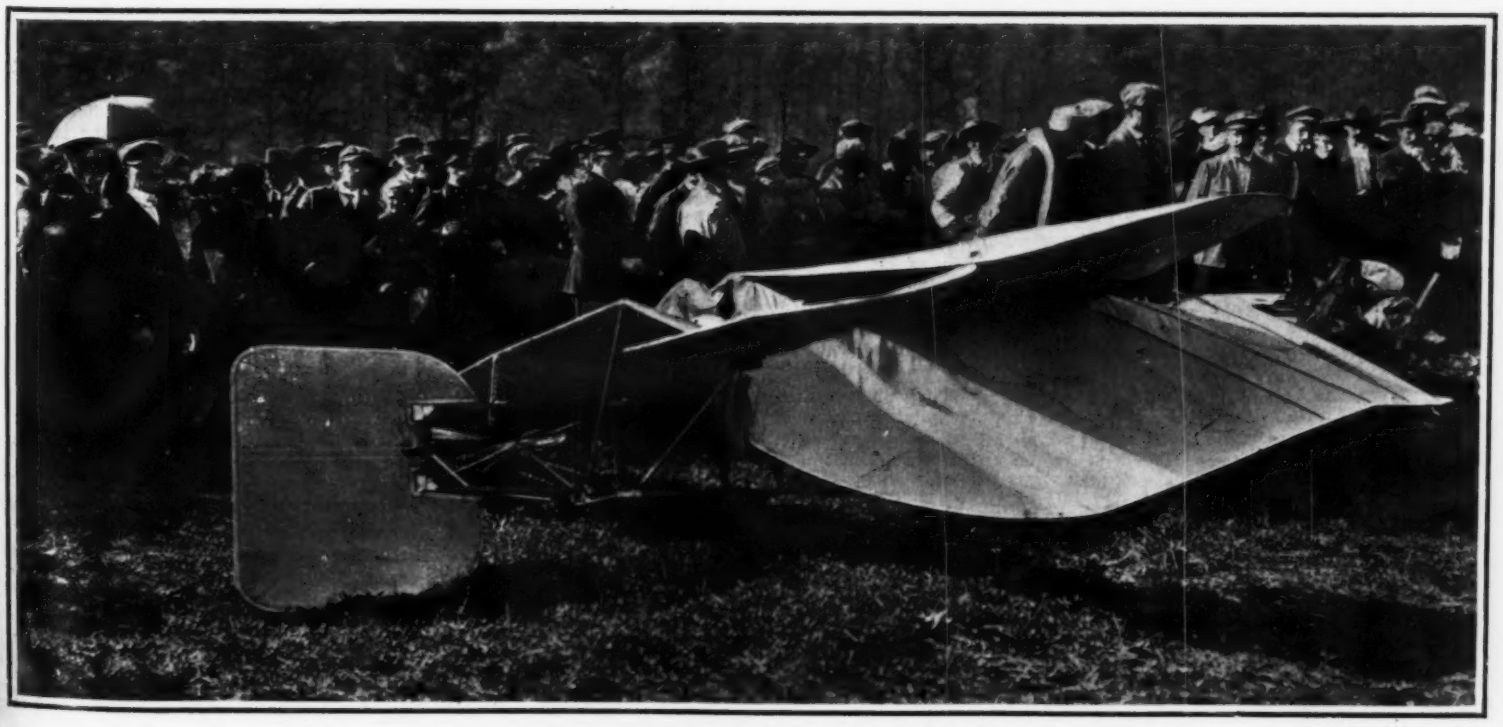
There were originally 13 entries, but of these only five were found qualified. They were:

Chavez, who holds the world's altitude record, which he won at Issy-les-Moulineaux, September 8th, when

THE ITALIAN SLOPE OF THE ALPS.

By courtesy of L'Illustration.

THE SWISS SLOPE OF THE ALPS.



THE END OF CHAVEZ'S HEROIC PASSAGE OF THE ALPS.

THE FIRST PASSAGE OF THE ALPS IN AN AEROPLANE.

reaching 2,682 meters (8,790 feet, 1 2/3 miles) altitude.

Cattaneo, just in from the Odessa aviation meeting, and who has won so many exploits in England with the Blériot monoplane.

Wincziers, who made such a fine ascension over the spires of the Strasburg Cathedral.

Weymann, who distanced all competitors in the late trip from Paris to Clermont-Ferrand.

Paillette, who has distinguished himself in numerous important ascents throughout Normandy.

From the point of departure, just above the entrance to the great Simplon railway tunnel, the mountains are all very steep, and as, at a distance of about 8 kilometers, the ascent reaches 1,100 meters up to the Simplon Kuhn, where it is 2,009 meters, aviators must ascend to at the very least 2,200 meters—possibly to 2,500—before they can begin the descent toward the Saltina valley, which lies between the Kaltwasser and Fletschhorn glaciers. In descending, the aviator should properly leave the Simplon hospice (1,872 meters) on his right and follow the road leading to the Simplon village (1,730 meters), beyond which is Gaby and to the right the Lagin valley descending from the Wangenhorn glaciers. At this point, the aviator has two routes to choose from, the first being 33 kilometers in length and crossing the Gondo valley as far as Bugliago, presenting deep ravines and inaccessible rocks, thence to the small village of Frasquere, about 8 kilometers' distance, to the Toce River as far as Domodossola (Domo d'Ossola). The second route is from Gaby up the Furrg (1,882 meters), crossing the Vaira valley and again rising up the Monscera (Monchera) and along the valley to Domodossola. While at 25 kilometers from the starting point the altitude is 650 meters, Domodossola, which is 40 kilometers away, is only 277 meters above sea level. After Domodossola, the aviator should follow the railroad and the Toce River to the lone Orfano mountain, 710 meters high. Then on to Stresa, Lago Maggiore, and across the lake to Laveno, where will be passed on the right the Monte Ferro and the Campo dei Fiori, in order to reach the city of Varese. Finally, across the Tradate, passing Mozzate, Cislago, Saronno, to the aerodrome at Porta Vittoria, end of the route.

During more than half an hour before Domodossola is reached, aviators must fly above a mountainous region filled with jagged peaks, dazzling snowslopes, precipices of all kinds, making a landing utterly impossible, and they must by all means avoid the terrible gorges where they might strike easily the sides of many narrow passages. Everywhere are huge boulders, massive tree roots, bordering immense clefts, which extend all the way down the cliff some 1,200 feet into black chasms.

In these regions, the danger to the aviator is greater by reason of the decreased effectiveness of his apparatus. The motor which gives 50 horse-power at sea level can render but 35 horse-power at 2,000 meters, and the difficulty of managing the apparatus increases immensely with the ascent, for the wind currents are very violent and capricious, rapidly varying in direction and intensity, throughout the whole of the Simplon, thus preventing the maintenance of ordinary stability. It was demonstrated last winter, at St. Moritz, by Capt. Engelhardt that his aeroplane could not reach higher than 200 meters above that city, which is located at 2,000 meters altitude, and Latham once had to declare forfeit, as he found at the last that his motor could not be made to work well enough at even 1,200 meters altitude.

For the benefit of the contestants, a special telephone service was instituted, which united Brieg, Simplon, Domodossola, Stresa, Bareno, and Milan, also stations of wireless as well as of optical telegraph along the main peaks, and, besides, there were also installed many garages with all necessary supplies. The course had been marked by flags, pieces of white linen 30 meters long and 10 meters wide, captive balloons, and very many large smoke-producing fires. Surgeons, with automobiles, were posted at many of the dangerous points, ready to extend all needed assistance from their headquarters established on the Mundura plateau, situated at an altitude of 2,136 meters. In addition, the Verbano Yacht Club had organized a service of automobile boats patrolling the Lago Maggiore.

This aeroplane crossing of the Alps was to serve as a grand prelude to the aviation meeting of Milan, at which some 320,000 francs are to be competed for by forty-five different aviators.

Of the above-named aviators, Chavez, Cattaneo, and Paillette employ the Blériot, with Gnome motor of 50 horse-power, upon which the rear wheels have been replaced by rails to facilitate landing, but Weymann intended using a Farman biplane designed especially for this contest, it being made quite small and of very light weight, the better to enable it to fly at greater height.

The intention of Chavez was originally to rise 1,000 meters from the ground and go directly to the Simplon, taking at Gaby the Col de la Monscera and avoiding the exceedingly dangerous Gondo valley with its steep elevations. When at Domodossola, he was to land for motor supply. The balance of the trip he considered comparatively easy, for the road to Lago Maggiore and through Lombardy to Milan actually presents no very serious difficulties. Cattaneo said he would land as far as possible from the starting point, probably at Varese. What he feared most was the severe cold to be sustained in the Alps, both by man and motor, for, in the event of the oil freezing, a fall would ensue, and he took the precaution to cover all exposed parts of machinery thickly with asbestos. The other aviators took the same precautions, but did not make known their final plan of operations.

Sunday, September 18th.—A truly magnificent day, clear, sunny, mild, and windless, which all the aviators appeared anxious to avail of, but, unfortunately, they were not allowed to do so under penalty of disqualification, by reason, it was said, of its being a day of national thanksgiving, celebrated throughout the whole of the Canton of Valais. Chavez was especially irritated at the enforced delay, for he was in complete readiness and had just finished a personal automobile survey of the Saltina valley. All his apparatus was protected as much as possible and he had even incased his barometer in aluminium, realizing, said he, that its good behavior was almost as necessary as the regular working of his 50 horse-power Gnome. Cattaneo announced his abandonment of the proposed trip, as evening came, when he learned that the wind was increasing in force, already blowing at the rate of 10 meters per second at the summit of the Simplon Pass, and that the clouds were thickening at a rapid rate all along the Monscera.

Monday, September 19th.—Chavez and Weymann drew lots to see who should start first. Chavez won and was under way on his monoplane at 6:16 A. M. At 6:30 he had disappeared in the direction of the Simplon, where he was soon followed by Weymann in his small biplane, but they both failed to proceed and had to return. Weymann attributed his failure to the fact that his new biplane was not yet in complete working order, notwithstanding all the modifications brought to it by Henry Farman. Chavez said that after passing over the Hohgebirg (2,018 meters) and the Aletsch (largest glacier of Switzerland) he had reached 2,300 meters, and while in the direction of the Col du Simplon he fell in with such violent whirlwinds as he had never before seen. They threatened to hurl him every moment from his seat, and as the mist was thickening he deemed best to return, making the descent in three minutes and reaching the plain at 6 h. 35 min. 53 sec., having spent only 19 min. 33 sec. on the trip. He said that his Gnome revolved very satisfactorily, making 1,100 turns at the 2,300-meter elevation. Paillette and Wincziers, following Cattaneo's example, announced their withdrawal from the contest.

Tuesday, September 20th.—The wind, hail, and rain made it impossible for the aviators to attempt crossing the Simplon. It had stormed all night and the sky remained covered, the summits of the mountains having disappeared in masses of low clouds which rolled down the sides, completely enveloping the slopes in thick mist.

Wednesday, September 21st.—A severe gale in the Rhone valley again delayed flight over the Alps and compelled the aviators to impatiently wait at Brieg for a moderation of the wind. The storm center had shifted from the Italian side to the Rhone valley, where a north wind continued to blow very fiercely throughout the entire day.

Thursday, September 22nd.—Weather still baffled aviators at Brieg. Severe cold was reported from Simplon Kulm, where the gathering clouds hid view on all sides. It was also bitterly cold at Brieg and in the valley, while it began snowing hard from 3 o'clock. Notwithstanding these unfavorable weather conditions, Weymann made three different flights, one as high as 1,700 meters with a *vol plané*. He now regrets he did not bring with him the aeroplane on which he flew to Clermont-Ferrand, as he fears the new one he has is of too small a type, adapted more for speed than climbing.

Friday, September 23rd.—The Alps, for the first ti...

CHAVEZ STARTING FROM BRIGUE.

CHAVEZ CLIMBING OUT OF HIS MACHINE.

THE FIRST PASSAGE OF THE ALPS IN AN AEROPLANE.

were crossed by George Chavez in an aeroplane, although his triumph was marred, when only about fifteen feet from the ground, by an accident through which he broke both legs besides sustaining other very severe injuries from which he died.

The weather was exceedingly fine, cold yet clear. Weymann made a trial ascent at 1:10 P. M., but landed in six minutes. Chavez hesitated when informed that the wind was very strong and that the latest observations showed three degrees of frost on the Simplon Kulm, but, after making a hurried automobile trip up the road, he decided to start. Briefly stated, he rose at 1:29 P. M. very gracefully, circled for a while, then flew straight toward the Simplon Kulm, which appeared free of clouds, and he was lost to sight at 1:40. He crossed the Kulm at 1:48 in a high wind, showing that in 18 minutes he had increased in altitude from 870 to 2,910 meters. Then he passed to the right of Kulm, and at 2:05 crossed the Col de la Monscera, the height of which is about 2,500 meters. At 2:11, forty-two minutes after his departure, he touched ground on a plain about five kilometers from Domodossola. The account of the trip which Chavez has been able to give, while lying at the San Biagio Hospital, is as follows:

"It is terrible to have been stopped like that by such a stupid accident, when the most difficult part of the journey had already been accomplished. I had studied all the details of the route, and felt quite sure of success. My departure was just like the one that I had made on Monday. I rose in circles, and then went straight for the Simplon. The signals along the way were of excellent service in directing me. After the Simplon I had to struggle with the wind, which was exceedingly strong. At Gaby, where I had to choose between the Gondo and the Monscera routes, I perceived that I was not high enough to get over the Col de la Monscera, where I ran a great risk of coming into contact with the mountain. In order to attain the necessary altitude I should have had to describe a long spiral turn, which is a terrible thing when a strong wind is blowing.

"My aeroplane was going at full speed. I took the Gondo. I flew on at a tremendous rate, and reached the Domodossola valley without knowing how I had done it. The speed must have been fabulous. But I cannot remember anything. The wind blew in violent gusts, and I went up and down. Suddenly, in the Domodossola valley, I found the atmosphere perfectly calm. Below me I saw people, who were waving their arms and flags. I had arrived. I went down. I was surprised by the accident. The wings broke. What I feel most is that I did not succeed in reaching Milan."

The Milan Aviation Association has decided to present to the brother of Chavez a prize of 50,000 francs, and is planning to erect a monument, where Chavez fell, in commemoration of his plucky flight.

NEW LINEAR EXPANSION APPARATUS.*

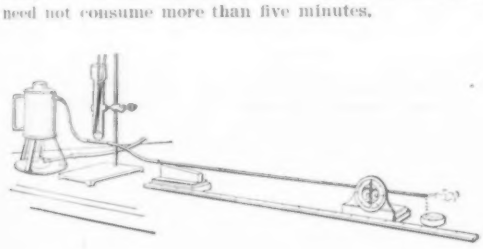
AN INSTRUMENT FOR MAKING NUMEROUS DETERMINATIONS IN A SINGLE STUDENT'S LABORATORY PERIOD.

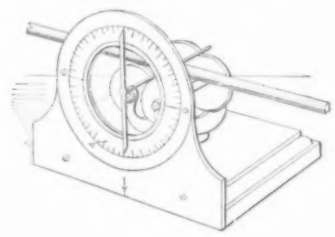
BY GEORGE A. COWEN.

THE design of this apparatus is such that it is possible for the student to take a large number of determinations during a single laboratory period.

It is found that where the student works with varying length of the same material, and also with different materials, that his knowledge concerning linear expansion is much more definite and real. In the apparatus here referred to, glass as well as metal tubes may be used, obtaining results of a degree of accuracy not usually obtained with the ordinary type of apparatus.

The greater number of determinations in a given period obtained with this apparatus is made possible by the ease with which water may be passed through the tube immediately after the steam is shut off. The complete record with the given length and material need not consume more than five minutes.





Referring to the cut, the tube is held at one end by a thin strip of metal which engages in a file- or saw-cut in the tube. When a glass in place of the metal tube is used, the method of securing this end is varied by putting on the tube a short section of rubber tubing in the surface of which a V-shaped cut is made.

PUPIL'S RECORD. OLD STYLE.	PUPIL'S RECORD. NEW STYLE.	INSTRUCTOR'S RECORD. NEW STYLE.
0000 150	0000 171	0000 175
" "	" "	" 176
" "	0000 172	" "
0000 156	0000 173	0000 177
" "	0000 174	" "
0000 158	0000 175	" "
0000 159	" "	" "
0000 165	" "	" "
" "	" "	" "
0000 166	0000 176	" "
0000 167	" "	" "
0000 169	0000 177	" "
0000 173	" "	" "
0000 176	" "	" "
0000 177	" "	" "
0000 180	" "	" "
0000 181	" "	0000 178
0000 183	" "	" "
0000 184	0000 178	" "
0000 186	" "	" "
0000 187	" "	" "
0000 189	" "	" "
0000 194	" "	" "
0000 195	" "	
0000 196	0000 179	
0000 200	0000 180	
0000 216	" "	
	" "	
	0000 181	

The free end of the tube rests upon the axis of the indicator. This axis rests upon roller bearings so adjusted that the rolling friction of the wheels is less than the sliding friction of the tube on the axle, so that as the tube expands the axle revolves, carrying with it a light, evenly poised indicator, the amount of the expansion being determined by the relative rotation of the axle.

Different lengths of tube may be obtained by moving the indicating apparatus nearer to or further away from the fixed end of the tube. The linear expansion of the tube which is being used is easily determined by the meter stick placed as shown in the cut, there being a mark on the face of the base directly under the point of support.

Water Tank. To simplify the water tank problem the writer has found it convenient to use the student lamp chimney supported as indicated in the drawing. The temperature of the water is determined by reading the thermometer just before the water is allowed to pass through the tube. After the water has passed through, the index is set at zero. The hole in the rubber stopper is then closed by means of the solid glass rod. Steam from the boiler is allowed to flow through the tube until the expansion as indicated by the rotation of the index has reached its maximum.

Computation. If the diameter of the axis be 0.2 centimeter its circumference must be 0.62832 centimeter. If the index is moved through an arc of 60 degrees the expansion of the tube must have been 0.10472 centimeter.

For making a second determination the cold water which has previously been placed in the tank is allowed again to pass through the tube.

The wheels or roller bearings in the apparatus used to obtain the results given below were taken from the inclined plane car, while the dial was removed from the astatic galvanometer.

Expense. It is believed that this piece of apparatus will be much cheaper than the ordinary type, more easily handled and more readily comprehended by the pupil, while the results which the author has definitely determined will show errors with not more than 20 per cent of the error obtained by the older forms of instruments.

The tables below will show upon what the claim for accuracy is based. The laboratory directions given to the author's pupils will indicate how brief are the directions required.

In a class of about sixty pupils one-half used the lever type and the other half the new style. All the results are here tabulated, and there has been no attempt to select the best. The results obtained with the lever type lie between 0.000015 and 0.0000216. With the new apparatus the results lie between 0.0000171 and 0.0000181. It will thus be seen by examination of the tables that the third significant figure has some value.

REASONS FOR THE ACCURACY OF THE NEW APPARATUS.

Old.

An error of 0.5 millimeter in rise of pointer changes coefficient 0.0000007.

An error of 0.5 millimeter in length of short arm changes coefficient 0.0000003.

New.

An error of 0.5 millimeter in rise of pointer changes 0.0000001.

An error of 0.01 millimeter in diameter of axle changes ... 0.0000001.

The chief source of error seems to be in reading the thermometer.

Instructor's Record.

	TEMP. WATER DEG.	STEAM DEG.	ANGLE DEG.	LENGTH	COEFFICIENT
Brass	8	100	65	70 cm.	0000177
	14	100.2	62	70 cm.	0000178
	20	100	57	70 cm.	0000178
Aluminum	21	100.3	72	80 cm.	0000228
	21	100.3	72	80 cm.	0000228
	21	100.3	72	80 cm.	0000228
	21	100.3	72	80 cm.	0000228
Glass	6	100	38	70 cm.	0000100
	8	100	37.5	70 cm.	0000101
	19	100.3	42	90 cm.	0000100
	20	100	32	70 cm.	0000099

*School Science and Mathematics.

AFRICAN WILD SILKS.

AT the present time the most important African silk-producing insects are those of *Anaphe* species, belonging to the *Eupterotidæ*. The genus *Anaphe* occurs in many parts of Africa, and the following species have been recorded: *Anaphe panda* and *A. reticulata* in Natal; *A. infracta*, *A. Carteri* and *A. Moloneyi* in East and West Africa; *A. ambrizia* in Portuguese West Africa, Northern Nigeria and Uganda; *A. venata* in West Africa; *A. subsordida* in Lagos and Southern Nigeria, and *A. clarilla* in Rhodesia. The silkworms live in large companies and move together in search of food. The colonies or nests are of irregular shape and size; the larger ones containing a hundred or more cocoons, while others are small and contain ten or even fewer cocoons. The nests usually consist of several layers of silken material; the outer layers are somewhat coarse and loosely spun, while the inner layer is hard and of a parchment-like texture. The nests and single cocoons are usually of a dull reddish-brown color, but it is stated that when the worms are inclosed in the dark they spin white cocoons. The silk-worms are said to feed principally on the leaves of species of *Ficus*, but the nests are found on almost all forest trees. *Anaphe* silk contains a considerable quantity of "gum," which is more resistant to the action of ordinary degumming media than that of *Bombyx* or Tussur silk. Experiment has shown that treatment with alkali and soap solution will effect the removal of the gum. Specimens of nests, which have been examined, have been found to yield about 33 per cent of clean degummed silk. This figure must be regarded as approximate only, since the composition and size of the nests vary to a considerable extent. *Anaphe* silk resembles *Bombyx* silk and is capable of being spun into satisfactory yarn, but, unfortunately, the actual yield of clean degummed silk is very small. Whether a constant supply of the material can be obtained at such a price as to render its collection and manufacture profitable has not yet been definitely established.

How two stereoscopic pictures on one plate can be made has been revealed by E. Estanave. He shows that when the grating placed in front of the photographic plate has horizontal lines as well as vertical ones, suitable exposure through an objective with four apertures at the corners of a square give the necessary elements from which are obtained two different stereoscopic pictures on the one plate.

THE PRACTICE AND THEORY OF AVIATION.—I.*

THE LEADING AEROPLANES.

BY GROVER CLEVELAND LOENING, A.M.

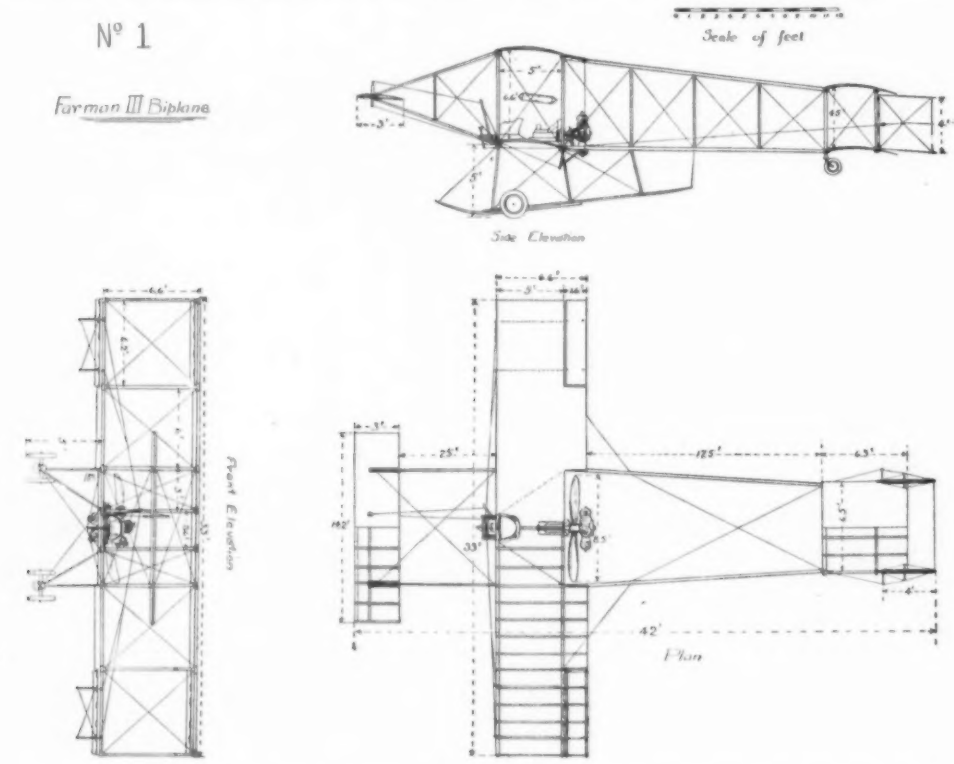
The Present Successful Types of Aeroplanes.

PART A. DESCRIPTION OF THE MOST PROMINENT TYPES.

Introduction.—The rapid progress that has been made in the practical application of the principles of Aerodynamics is almost unparalleled in the history of science. Within a year the number of men making extended flights has so greatly increased that we are warranted in classing artificial flight with other established means of locomotion.

The development of the aeroplane has been accompanied by the improvement of the dirigible balloon or aeronat, as technically termed; and the advance of both can undoubtedly be traced to the combination of high power and low weight offered by the gasoline engine.

In the case of aeronats, however, as early as 1884 the non-rigid type that we have to-day had been practically developed in the dirigible "La France," built by Col. Renard; and although much progress has been made, it has been more in the line of actual construction than in the development of any new principles.



The successful aeroplanes which have been evolved, although similar in their fundamental characteristics, have begun to vary from each other in many important details of size, arrangement and efficiency of parts. It seems, therefore, that we are at a stage where an examination of these various types for the purpose of comparison, and a discussion of their distinguishing features, merits, and demerits would prove of value.

It is to be borne in mind that inasmuch as aviators are constantly changing and rechanging the dimensions of their machines, without recording such alterations, many of the dimensions given here are necessarily approximate. In all cases, however, the most recent and accurate data as furnished by the large number of references consulted, as well as by close personal inspection, have been made use of.

In the science of aeronautics it has been necessary to use a number of new terms. By "supporting plane" is meant the main lifting surface as distinguished from all auxiliary or stabilizing surfaces. The term "direction rudder" refers to the movable vertical surface used for steering to right or left, while the "elevation rudder" is that horizontal surface which is used for steering up or down. "Transverse control" is the device used for the preservation of lateral balance in wind gusts, and for artificial inclination when making turns. "Keels" are fixed surfaces exerting neither lifting effect nor rudder action. "Spread" is the maximum horizontal dimension perpendicular to the line of flight, while "depth" is the dimension of the plane parallel to the line of flight.

By "aspect ratio" is meant the ratio of spread to depth, a means of defining the shape of surface.

In the following paragraphs the fourteen most prominent and distinct types are described in detail. These include seven biplanes:

1. The Farman.
2. The Cody.
3. The Curtiss.
4. The Wright.
5. The Voisin.
6. The Voisin (new model—tractor screw).
7. The Sommer.

And also seven monoplanes, including:

8. The Antoinette.
9. The Santos Dumont.
10. The Blériot XI.
11. The Blériot XII.
12. The Grade.
13. The Pelterie.
14. The Pfitzner.

Many other types of successful biplanes and monoplanes are in use, but they differ so slightly from one or the other of these types that they need not be separately described.

The Tellier and Hanriot monoplanes are very similar to the Antoinette, while the Koechlin, Hoffman, and many English monoplanes resemble the Blériot XI.

The order in which the types are taken up is merely a convenient one adopted here and is not based on any quality of the machines. The biplanes and the monoplanes are separated, as they represent two distinct systems.

Many other systems of heavier-than-air machines have been constructed, including several triplanes and some extremely interesting helicopters and ornithopters, but as yet none of these has demonstrated successful flying qualities.

For the purpose of more clearly showing the variation in size of the different types, detailed and dimensioned plans and elevations of each machine are given. Most of these are drawn to the same scale, thus enabling a direct graphic comparison of the types.

I. THE FARMAN BIPLANE.

Henri Farman, in 1907, began his career as an aviator by making short flights of a few seconds duration on a biplane constructed for him by the Voisin brothers. On January 13th, 1908, he succeeded in flying one kilometer in a closed circuit, thereby winning the Deutsch-Archdeacon prize, the first great prize offered for an aeroplane flight. Until the end of that year Farman flew this machine and with it conducted a series of experiments on stability. In the early part of 1909, having severed his connection with the Voisins, Farman opened an aeroplane factory at Chalons, France, and began manufacturing aeroplanes himself. His design was original in many ways, and embodied several practical innovations that his previous experience had suggested.

The Farman biplane is used extensively in Europe, and notably by the well-known aviators Paulhan, Weyman, White, etc. More than one hundred of this type are in use or under construction, and for a slow but trustworthy machine it has been found very satisfactory.

The Frame.—The frame consists essentially of a main box cell, somewhat similar in design to a Pratt truss, counterbraced throughout, with identical upper and lower chords, uprights of wood acting as compression members and cross wires as tension members. This construction is common to all biplanes considered here. The supporting planes are analogous to the upper and lower decks of such a truss.

The Supporting Planes.—There are two main carrying surfaces, identical and directly superposed. Their sectional curvature is of the pterygoidal shape, so generally used in present day aeroplanes. The curvature is concave on the under side, and of parabolic character. The surfaces are made of "Continental" cloth, a special rubber fabric stretched tightly over ash ribs. The spread of the surfaces = 33 feet; depth = 6.6 feet, and the total area = 430 square feet. The distance between planes = 7 feet.

The Elevation Rudder.—The elevation rudder consists of a single surface, about 43 square feet in area, situated well out in front. It is hinged and braced to two sets of outriggers, firmly attached to the main cell, and is controlled by a large lever in the aviator's right hand. By pulling in on this lever, the rudder is tilted up and the machine is caused to rise. By pushing out on the lever, the rudder is dipped down and the machine is caused to descend. This method of control is almost instinctive and very easy to acquire.

The Direction Rudder.—Two equal vertically placed surfaces in the extreme rear serve as the direction rudder. They are moved jointly and have an area of approximately 30 square feet. A foot lever, hinged at its center, is so connected to these rudders by cables that when the aviator pressing on this lever with his feet turns it, for example, to the left, then the machine will turn to the left.

Transverse Control.—The control of the lateral equilibrium, i. e., the tipping from side to side, is effected by the use of "wing tips," four flaps constituting the rear ends of each plane. A lever in the aviator's right hand (the same one as used to operate the elevation rudder) can be moved from side to side. It is connected by wires to the lower flap on either side. These flaps in turn transmit the movement imparted to them by the lever to the flaps directly above them by means of a further wire connection. When the machine is standing still the flaps merely hang down loosely and the wires relax. But as soon as the machine takes to flight the flaps fly out, very much like a flag blown by the breeze, and in this position the connecting wires are extended their full length, and the lever is in control.

If now, for example, the machine should tip suddenly down on the aviator's right side then the lever is promptly moved over to the left. This action causes the flaps on the right end of the machine to be pulled down, and since this involves an increased angle of incidence of the flaps, the lift they exert is increased. This is sufficient to bring the machine back to an even keel. During this process the wires leading to the flaps on the other end have been relaxed, since both sets of connecting wires are taut only when the lever is in mid-position. The flaps on the opposite end, therefore, have in no way been affected, except to be able to fly out more freely in the wind stream.

When making turns, in addition to using the direction rudder, the machine is often artificially inclined by the use of the transverse control. When turning to the right, for example, an instant before setting the direction rudder the lever is moved over to the right side. This lifts up the left end of the machine and therefore causes the turn to be sharper.

Keels.—Two horizontal surfaces at the rear of approximately 80 square feet area act as keels. Their angle of incidence is low, and the lift they exert is small, their only function being to steady the machine longitudinally.

Propulsion.—A 50 horse-power 7-cylinder, Gnome rotary, air-cooled motor is mounted on a shaft in the rear of the lower plane. A two-bladed Chauviere wooden propeller is directly connected to this motor, and rotates with it at 1,200 r.p.m. The pitch of the propeller is 4.62 feet and its diameter 8.5 feet.

* Accepted as thesis for the degree of A.M., Columbia University, June, 1910.

The Seats for aviator and two passengers are placed on the front of the lower plane.

The Mounting, or apparatus upon which the machine starts and alights, consists of two long skids forming part of the framework, upon each of which is mounted a pair of wheels. When starting, this machine runs along the ground on its wheels, but when alighting, the wheels, which are attached to rubber springs, give way, and the machine lands on its skids.

The total weight varies greatly with the amount of gasoline taken aboard, the number of passengers, etc. The limits within which this value lies, however, are given and all calculations are made for an approximate mean weight of the machine with aviator aboard ready for flight. The weight of the Farman machine is from 1,100 pounds to 1,350 pounds; the speed, 37 miles per hour; 24 pounds are lifted per horse-power and 2.8 pounds per square foot of surface. The aspect ratio is 5 to 1.

Recent Alterations.—The more recent types of Farman machines are fitted with a single surface direction rudder, instead of the twin surfaces. The elevation rudder, in front, is made smaller, and in addition the rear end of the upper of the two fixed horizontal keels (at the rear of the machine) is made movable conjointly with the front rudder to control the elevation of the machine. In some of the machines only one surface is used at the rear.

The two small wheels supporting the rear cell are replaced by a single skid. Other characteristics are substantially as given.

The new racing type of Farman has the following characteristics: The surface is reduced to 350 square feet, and the spread to 28 feet. The total weight in flight is about 1,050 pounds. Twenty-one pounds are lifted per horse-power, and 3.0 pounds per square foot of surface. The aspect ratio is 4.2 to 1.

Another recent type of Farman is the huge new passenger-carrying machine, which now holds the four-passenger record. This aeroplane has a surface of about 540 square feet, and a spread of 47.6 feet. The maximum total weight is nearly 1,750 pounds, thus giving a capacity of 34 pounds per horse-power and a loading of 3.15 pounds per square foot of surface. The aspect ratio is 7.1 to 1.

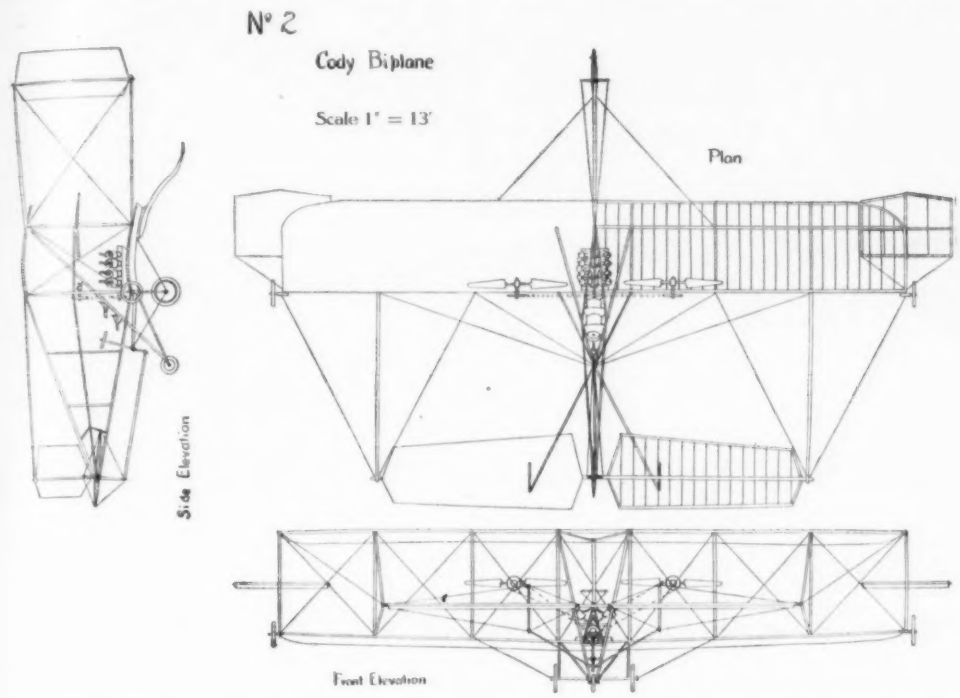
References.—Aerophile, v. 17, p. 220, p. 488; Aeronautics, v. 4, p. 206; v. 5, p. 218; Flight, v. 1, p. 641; Flug Motor Tech., No. 22, p. 10; Boll. Soc. Aer. Italiano, v. 6, p. 288; Locomocion Aerea, v 1, p. 78; Aeronautics (Brit.), v. 2, p. 117; SCI. AM. SUP., v. 68, p. 324; La Nature, v. 37, p. 329.

2. THE CODY BIPLANE.

Col. Cody, an American, who has for some time resided in England, distinguished himself several years ago as the successful operator of man-lifting kites. His work in this line, with regard to army use and scouting, attracted much attention in England. In 1907, Col. Cody commenced work on a motor aeroplane of huge dimensions. At first the tests of this machine were very unsuccessful, but with remarkable perseverance Col. Cody gradually turned the failures into successes, and finally in the late summer of 1909 he accomplished a superb flight of over an hour, establishing the cross-country record of the world. The machine has been altered many times, and in its present form is the largest successful aeroplane in use to-day.

The Frame.—Bamboo is used extensively throughout the frame, but all joints are carefully wound with steel wire. In addition there are many upright members of ash. At the center several members meet in the supporting chassis, which is very heavily built. Steel wire is used for bracing.

Supporting Planes.—The main planes are rectangular in shape with rounded rear edges and are identical and directly superposed. The surfaces are made of canvas stretched tightly over wooden ribs. At the center the distance between them is 9 feet, but they converge toward either end, and are there separated by only 8 feet. The spread is 52 feet, the depth 7.5 feet, and the area 780 square feet.



The Elevation Rudder.—At the front of the machine, supported by large bamboo outriggers from the central cell, are two equal surfaces on either side of the center. These are jointly movable, and serve to control the elevation of the machine. They are governed by the forward or back motion of the stanchion upon which the steering wheel is mounted. If the aviator wishes to rise he pulls the wheel toward him. This motion, by means of a lever system, causes the elevation rudder surfaces to be tilted up to the line of flight and the machine ascends.

The Direction Rudder.—For steering to one side or the other two surfaces are used. At the rear of the machine is a large vertical surface, which is the main direction rudder, while at the front is a smaller vertical surface used for the same purpose. These rudders are moved jointly by a cable and steering wheel, as in automobiles or motor boats. Their area is about 40 square feet.

Transverse Control.—Two balancing planes of 30 square feet area, one placed at either end of the main cell, control the transverse inclination of the machine. They are moved inversely by cables leading from the steering gear at command of the aviator. If the right end of the machine should be depressed, then the wing tip on that side is turned down, but at the same time the wing tip on the other end is turned up. This causes not only the depressed side to rise, but also the raised side to be depressed, thus righting the machine. When making turns the machine can be artificially inclined with this apparatus. In addition to the wing tips, the transverse equilibrium can be controlled by the inverse movement of the two halves of the elevation rudder, the one on the depressed side being elevated while the other is turned down.

Keels.—There are no keels in this machine, all surfaces serving either to lift or to direct the aeroplane.

Propulsion.—The motive power is an 80 horse-power E.N.V. 8-cylinder motor. Two two-bladed propellers placed at the front of the main cell are driven in opposite directions by chains at 600 r.p.m. Their diameter equals 8.25 feet, and their pitch 6 feet.

The Seats for aviator and one passenger are placed low at the center in front of the main cell. The lower seat is for the aviator, while the other was designed for the use of an observer in war time to take sketches of the enemy's position, etc.

The Mounting consists of a large pair of wheels, which carry most of the weight, a small wheel in front of them, and a skid in the rear. Wheels are also fixed on each end of the lower plane to carry the machine easily over the ground if it should alight on one end.

The total weight is from 1,900 to 2,100 pounds; the speed, 37 miles per hour; 25 pounds are lifted per horse-power, and 2.57 pounds per square foot of surface. The aspect ratio is 7 to 1.

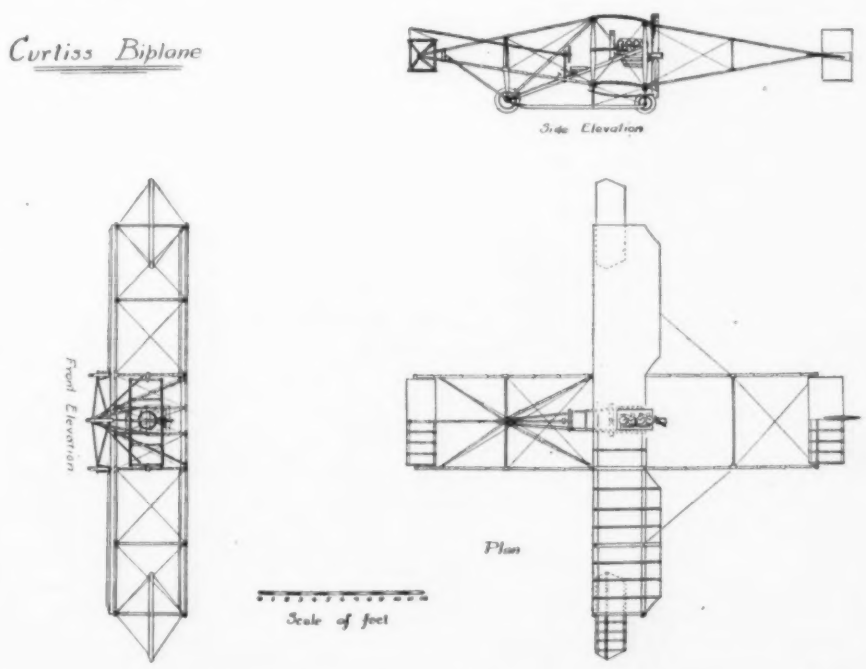
Recent Alterations.—Col. Cody has recently altered his biplane. The E. N. V. motor has been replaced by two 50 horse-power 4-cylinder Green motors, both driving a single propeller instead of the twin propellers formerly used. Either motor can be operated individually, the main advantage of this disposition being that if one motor breaks down while in flight, the other can still be used to drive the machine.

References.—Zeit. Ver. Deut. Ing., v. 53, p. 1143; Aeronautics, v. 4, pp. 78, 126; v. 5, pp. 33, 65, 154; Flight, v. 1, pp. 113, 501; Encyl. d'Av., v. 1, p. 112; Boll. Soc. Aer. Ital., v. 6, p. 288; Vorreiter A., "Motor Flugapparate"; SCI. AM., v. 101, p. 198.

3. THE CURTISS BIPLANE.

The Curtiss biplane, manufactured by the Herring-Curtiss Company, embodies in its construction several features that distinguished the aeroplanes built by the Aerial Experiment Association, of which Mr. Curtiss was a member. In June, 1909, the first flight of this type was made. At Rheims, in August, this miniature biplane, ably piloted by Mr. Curtiss, captured the Gordon Bennett Prize and Cup as well as several others. It is one of the fastest biplanes now in use. Several machines of this type are being flown, notably by Messrs. Curtiss, Mars, Hamilton, Willard, McCurdy, Ely, Post, and Baldwin.

The Frame.—The main cell and smaller parts are made of ash and spruce, and the large outriggers of bamboo. Several members of the frame meet at the front wheel. Small cables as well as wires are used for bracing.



The Supporting Planes.—The main carrying planes are of very finished construction. They consist of two identical directly superposed surfaces made of one layer of Baldwin rubber silk, tacked to spruce ribs and laced to the frame. A distance of 5 feet separates the

surfaces. Their spread is 26.42 feet, the depth 4.5 feet, and the area 220 square feet.

The Elevation Rudder.—The elevation rudder is a small biplane cell consisting of two identical surfaces, 24 square feet in area, mounted at the front on bamboo outriggers. It is governed by a long bamboo rod attached to the stanchion on which the steering wheel is mounted. By pushing out on this, the rudder is turned down and the machine descends. By pulling in, the machine is caused to ascend.

The Direction Rudder.—The rudder for steering from right to left consists of a single vertical surface placed in the rear and operated by the steering wheel and cables, which are run inside the bamboo outrigger. Its area is 6.6 square feet.

Transverse Control.—Two balancing planes of 12 square feet area each, one placed at either end of the main cell, are used to preserve lateral balance. They are tipped inversely by means of a brace fitted to and swayed by the aviator's body. If the machine is depressed on the left side, the aviator leans toward the right, and in so doing moves the brace, causing the wing tip on the left side to be turned down and the one on the right to be turned up, thus righting the machine. By "turning down" is here meant a motion relative to the axis of the wing tip itself and not to the line of flight. When a wing tip of this sort is turned down, its incidence, i. e., the angle it makes with the line of flight, is positive and it therefore exerts a greater lifting force.

When making a turn to the right, for example, the aviator, by leaning to the right, and thus causing the left end to lift up, can make a sharper turn than by use of the direction rudder alone.

Keels.—A horizontal fixed surface is placed in the rear and steadies the machine greatly. Its area is 15 square feet. A small triangular vertical surface is sometimes placed in front and aids in turning.

Propulsion.—A 25 horse-power, 4-cylinder Curtiss motor, placed well up between the two surfaces at the rear, drives direct a two-bladed wooden propeller at 1,200 r.p.m. The propeller has a pitch of 5 feet and a diameter of 6 feet.

The Seat for the aviator is on the framing in front of the main cell and in line with the motor. When a passenger is carried a seat is provided to the side and somewhat below the aviator.

The Mounting is on three rubber-tired wheels, rigidly fixed to the frame, no springs being provided.

The total weight is from 530 to 570 pounds, and the speed is 47 m.p.h.; 22 pounds are lifted per horse-power and 2.5 pounds per square foot of surface. The aspect ratio is 5.65 to 1.

Recent Alterations.—Mr. Willard has recently begun flying a larger type of Curtiss biplane, in which he has succeeded in carrying three passengers besides himself.

This machine is precisely of the same general design as the regular Curtiss type, but differs from it in size.

The supporting planes have a spread of 32 feet, a depth of 5 feet, and an area of 316 square feet. The elevation rudder is 31 square feet in area, and the direction rudder 7.5 square feet in area. The rear horizontal keel has an area of 17.5 square feet, while the ailerons are each 27 square feet in size. A Curtiss 8-cylinder 50 horse-power motor is used and drives direct a 7-foot propeller at 1,100 r.p.m. The maximum total weight in flight is 1,150 pounds. 22.6 pounds are carried per horse-power, and 3.64 pounds per square foot of surface. The aspect ratio is 6.4 to 1.

References.—Aeronautics, v. 5, p. 13, 86, 137; Am. Aeronaut, v. 1, p. 1 (new series); Boll. Soc. Aer. Ital., v. 6, p. 286; SCI. AMERICAN, v. 100, p. 460; Encycl. d'Av., v. 1, p. 24; Am. Machinist, v. 32, p. 49; Flight, v. 1, p. 389; Zeit. für Luft., v. 13, p. 816; Aerophile, v. 17, p. 488; Locomocion Aerea, v. 1, p. 78; Genie Civil, v. 55, p. 343.

(To be continued.)

THE WATER SERVICE OF A PLANT.

THE ACCUMULATION OF WATER BY DESERT PLANTS.

BY DR. D. T. MACDOUGAL, DESERT LABORATORY OF THE CARNEGIE INSTITUTION.

THE activities of the seed plant make necessary a movement of solutions from the surface intakes of roots or other absorbing organs in contact with the medium or substratum to various tissues, the residue of liquid and content finally reaching the excretory or transpiratory membranes of the leaves, stems or other aerial members.

This water service involves a supply of available moisture in the substratum or medium, absorbing organs, whose tissues sustain a relatively higher turgidity than the substratum, conducting tracts of adequate capacity, and transpiratory organs, which in response to the evaporating action of the air, throw off the water of the solutions entering the roots, in the form of vapor, at a rate variously modified by the purely physiological activity of the protoplasts.

The rainfall in many desert regions is all received within very limited periods, and the soil of such places may not contain sufficient moisture to allow of absorption by plants for more than a few weeks in the entire year. It seems quite natural therefore that many of the plants peculiar to such regions should display a capacity for accumulating a large balance during the rainy seasons, which may be expended in the activities of the organism during the long, dry periods. The surplus water may be stored in thick fleshy leaves, as in Agave, or in fleshy stems as in the Cactaceæ, or in roots, as in some of the members of the squash family.

Succulents are such a prominent constituent of the flora of the arid regions contiguous to the Desert Laboratory of the Carnegie Institution of Washington, that it was thought necessary to obtain some information as to the behavior of their water balance in order to gain a general comprehension of the physiology of the striking types of vegetation characteristic of deserts. A long series of measurements was therefore made to determine the amount of the water balance carried by some of these forms, its variations, the factors which operate to deplete it or to permit its increase, and the relation of the balance to growth and reproduction. Attention was directed chiefly to the great tree cactus (*Carnegiea gigantea*), the barrel cactus (*Echinocactus*), and the prickly pear (*Opuntia discata* and *O. blakeana*).

Healthy specimens of these fleshy plants were taken from the soil without injury and placed on a series of "silk" scales, by which variations in weight might be followed for extended periods, both in the open and in shaded rooms.

Chemical analyses of the sap were made to determine the changes which ensue in a plant during the depletion and during the repletion of its water supply.

In order to obtain data upon which to base an estimate of the amount of water in the bodies of the sahuaro, or tree cactus, an individual consisting of a single columnar trunk growing near the southwestern corner of the domain of the Desert Laboratory was cut down on October 17th, 1909. It was found to be in a condition of extreme turgidity, and measured 5.6 meters in length, representing the height above the surface of the soil, while the diameter at the swollen middle portion was 60 centimeters. The trunk was cut into sections of about 60 kilogrammes, which were weighed on a balance having a draft of 100 kilogrammes, the whole plant having a draft of 767.8 kilogrammes. A sample including one ridge with spines, and a section of the cortex, and wood extending to the center of the medulla, was taken for a water determination. Its weight was 3.024 kilogrammes, and the residue after drying was 276 grammes, indicative of an original water content of 2648 grammes, or 91 per cent of the sample. The entire plant therefore held 698.5 liters of water.

Plants of the maximum size attained in different localities 12 to 20 meters in height and 75 to 100 years old would therefore contain from 2,000 to 3,000 liters of water, and a few individuals have been seen which would exceed this amount. Over half, perhaps three-fourths, of this amount might be lost without actual injury to the ordinary processes of the plant, but growth would not ensue if the water balance were depleted to this extent. Furthermore, the rigidity of the stem is largely a matter of turgidity, and the lessening of the water balance would render the trunks especially liable to breaking or uprooting. It is notable that even the greatest losses of water sustained by these plants are quickly regained after a rain, so that a few days or a month is sufficient to restore the original plumpness of the stems and branches.

Smaller specimens were used for determining the rate of water loss. A healthy tree cactus 2 meters in height was set up in a natural position on a base of loosely piled stones where it might not absorb water from the soil. A year later it was found to have lost 60 per cent of its weight or nearly 70 per cent of its water, as it now weighed but 28.750 kilogrammes. During a portion of the period in which this plant was subject to desiccation it probably lost as much as 60 to 80 grammes (2 to 3 ounces) of water daily. After a section had been taken for chemical analysis the decapitated trunk was set in the soil and proved to be capable of growth. The portion which had been removed yielded a juice which contained 9.6 per cent of solid matter, or 2.8 per cent of ash, while the sap of a tree taken during the rainy season, when the water balance was at its fullest, was found to contain but 3 per cent of solid matter or 1 per cent of ash.

The presence of a great surplus of water in all parts of the plant has one singular consequence in the matter of the survival of living branches on dead trunks. The trunk may die and decay quickly by a black rotting process which leaves the bare woody skeleton holding aloft the green branches which are a few inches in thickness and may be several feet long. These branches may survive for a year, during which time they produce flowers as well as fruit.

The short stems and relatively enormous thickness of the echinocacti, together with the curved or hooked spines and amount of accumulated water which they contain, has caused them to be designated by a number of local names, such as "barrel cactus," "bisnaga," "desert fountain," etc. One or more of the South American species together with *E. emoryii* and *E. wislizenii* hold so much water, which is readily yielded upon crushing, that the sap is used as an emergency drink by the aboriginal tribes of both North and South America. The great body has a very thin central woody cylinder, occupying but little of the space within the plant, which is chiefly composed of a soft parenchymatous tissue with fragile strands of fibrovascular tissue running out to the nodal points.

The contents of these watery cylinders are easily available to the thirsty traveler. A large knife is convenient for decapitating the plant, but lacking this, the large curved spines may be burned away by a burning match or splint, and then the top crushed with a stone. Singularly enough, the apical newer tissues do not yield their juices so readily as the older parts, being leathery and retentive of the sap. After this is removed the underlying parenchyma may be crushed by pounding with a stake or stone, and the juice squeezed into the cavity from which the tissues were removed. A liter of refreshing fluid may be obtained by a skillful operator in a few minutes, and the rigors of thirst on many desert journeys have been mitigated by its means.

A great number of these plants were subjected to experimental tests, including a variety of conditions. Some of the experiences are of such interest as to be worth citing. Thus a large melon cactus weighing 18 kilogrammes was taken up in November, 1908, and by exposure to sun and wind lost 6 kilogrammes of its weight by May, 1909. After being set in the soil during the summer rains it quickly regained its former weight and in the autumn (October) showed a draft of 20 kilogrammes. Being again taken up and exposed it lost such an amount of water that it weighed 13 kilogrammes in May, 1910, or 2 kilogrammes more than under similar circumstances during the previous year, and this may be taken to be the amount gained by growth during the year.

Some remarkable survivals were found in plants deprived of water. Thus an echinocactus weighing less than 2 kilogrammes was taken from the soil in March, 1908, and exposed to the full action of the sun and wind for a year, after which it was taken into a shaded room, where twenty-six months after having had a supply of available water, it weighs about 500 grammes and is transpiring at the rate of 0.2 gramme daily. Similar behavior on the part of larger individuals has also been noted, and a large number of species of cacti are known which might be capable of continued existence with functional activity upon the basis of accumulated water for two or three years or even longer. The concentrations which ensue in the sap of this plant with the reduction of the water balance are quite as marked as those of the sahuaro. A plant which had lost about 45 per cent of its water by exposure to sun and wind yielded a juice containing 7 per cent of solid matter or 3 per cent of ash, while a specimen turgid with the surplus water taken in with the summer rains gave a sap that contained but 2 per cent of solid matter and 0.8 per cent of ash.

More striking examples of great water accumulations, however, are offered by plants in which the surplus is held in underground organs or parts of the plant

which exhibit but little activity of the chlorophyl contained in its tissues. A splendid illustration is offered by the "guarequi" of Sonora. This is a member of the squash family which forms a great swelling at the base of the stem as large as the crown of a large hat. This tuberous formation is woody, contains much starch and stored material and also a large proportion of water. During the warm rainy season thin stems are sent up to a length of a few yards, leaves are spread out to the light, and flowers mature the small fruits, during which time the thin roots have grown out from the base of the tuber and sucked in as much water as their capacity would permit, which is received in the tissues of the tuber. The whole period of moisture and attendant activity may not extend over fifty days. The rains cease, the roots die in the hot dusty soil, and the thin stems perish, their soluble contents being also sent down into the tuber, which now lies inert like a loose rock on the surface of the desert soil during the remaining three hundred or more days in the year. But it may do much more than this. With its great water balance it may display its seasonal activity during the next year in case the rains do not come or if the supply does not reach it for any cause. Thus one of these plants was brought from Sonora by the writer in 1902 and placed on a museum shelf in the New York Botanical Garden in April, 1902. Here lying on a bare board it has sent up its thin stems year after year, drawing upon its balance of moisture which is not replenished, and to which no addition has been made since August, 1901, so that it has now existed in a healthy normal state for nine years by use of its stored balance, and it is estimated that some individuals are in condition to live and carry out the normal functions for a quarter of a century upon the balance of water accumulated during the brief rainy seasons. The outer tissues of these plants are protected by a layer of corky tissues all but impervious to water vapor, and the water is held as if in a bottle.

The results of observations upon the general climatic conditions prevalent in the Tucson region and the facts brought to light by an inspection of the data obtained by weighing and measurement of native succulents, present some features of unusual interest. These may be briefly set forth in the following paragraphs. The annual cycle includes two seasons in which the soil moisture content is high and the relative humidity is at its maximum. During the summer rainy season the temperature may reach 115 deg. F., while in the winter wet season the temperatures are low, but rarely remain below the freezing point for more than a few hours. Alternating with these seasons in which moisture is more abundant are the dry fore-summer of April, May, and June, and the arid after-summer of August, September, and October, in which the temperatures are high and the relative humidity very low, sometimes falling to 8 and 10 per cent in June.

The rate of transpiration is largely determined by the evaporating capacity of the air, and this process operates to make a notable depletion of the water balance in plants under natural conditions during the dry fore-summer and after-summer. The influence of other conditions and of separate agencies may be detected, however. It was noted that individuals of the same species exhibited widely differing rates of loss as illustrated by Echinocacti, designated as Nos. 7 and 8. The former weighing 36 kilogrammes lost weight at a rate of 10 to 14 grammes daily in the month preceding January. 9th, 1909, while No. 8, under the same conditions of illumination, temperature, relative humidity, and wind action, showed a rate of 5 to 27 grammes daily, although its weight was but 29 kilogrammes. Both plants were in an inclosed room. Nos. 9 and 10 (Echinocacti) were exposed to open air conditions, and the first weighing 17 kilgrammes showed a rate of loss of 36 grammes daily for the month ending December 8th, 1908. No. 10 weighing 15 kilogrammes showed a rate of 61 grammes during the same period. No. 9 lost at the rate of 38 grammes daily during the six months ending May 12th, 1909, and No. 10, at the rate of 30 grammes in the same period. The conditions were more favorable for rapid transpiration in this plant than in No. 9. The disparity would doubtless have been even greater under equivalent conditions. Of the pair in the inclosed room, the larger lost most water during December, but the smaller showed a rate, low at first, but which increased until it was nearly double that of the plant which had a total weight one-fourth greater. The pair of plants in the open displayed a reverse relation. The smaller plant at first lost weight at the rate of 61 grammes while the larger gave but 36 grammes. Later the larger plant gave off more water than the smaller. Numerous other comparisons might be formulated, by reference to the results of weighings, and similar individuality of behavior was found by the long extended series of measurements. It is evident therefore that no equation expressive of relation of volume, water balance, and loss in weight may be formulated for the massive cacti described in the present paper.

The depletion of the water balance is of course less rapid during the second and succeeding years of exposure of detached plants than during the first year. The data obtained from observations on Echinocactus No. 1 serve as an example of this fact. The rate during the second year under equivalent conditions during corresponding seasons, is not more than 66 or even 55 per cent of that of the first year. In the absence of any information as to structural changes which might serve as a regulatory factor, the decrease of the rate may well be attributed primarily to the increased concentration of the sap and its consequent greater osmotic activity. Thus Carnegiea was seen to increase the proportion of mineral salts dissolved in the sap from 1 to 3 per cent, while Echinocactus made an increase from less than 0.8 to 3 per cent of dissolved salts.

The rate of loss of plants exposed in the open may be as much as four to eight times that of plants in inclosed but well ventilated rooms, in which the direct action of the wind and sun are eliminated. This is apparent even when the plants tested in the shade were much larger than those in the open.

Observations on a number of specimens show that some gain in weight may be expected in small specimens of Echinocactus detached and kept in well ventilated rooms, during January and December. This gain may be attributed to hygroscopic absorption by the dead spines. A small plant which had been desiccated for two years, when put in a dark room with equable temperature at about 60 deg. F., with the relative humidity 80 to 90 per cent during February, 1910, gained 2 grammes in ten days, and the same plant also increased its weight 4 grammes in 24 days in 1909, during the first year of its desiccation. It is to be pointed out that the water taken up in this manner could be of no practical use to the plant, since the fluid would be held so tenaciously by the tissues of the dead spines that it could not be withdrawn by the osmotic activity of the living cells.

An inspection of the proportions of organic material and ash shows no relative variation in the sap of plants in which the supply of water had been partially depleted by desiccation. The total solids in the juice of a turgid Echinocactus amount to 2.692 grammes per 100 cubic centimeters, of which the organic matter is 1.320 and the ash, 0.772. The total solids in a desiccated specimen amounted to 7.060, of which 4.060 was organic and 3 ash. The general concentration had been increased in the ratio of 2 to 7, the concentration of organic matter from 1.3 to 4, and the concentration of the ash as 1 to 3. The total solids dissolved in the sap of a turgid Carnegiea amount to 3.4 parts in a hundred, of which 2.4 is organic material and 1 ash. In the desiccated plant the dissolved solids amount to 9.6 parts in a hundred, of which 6.8 are organic and 2.8 ash. The general concentration was as 3.4 to 9.6; the concentration of organic material as 2.4 to 6.8 and of the ash as 1 to 2.8.

The depletion of the water balance in the cacti is accompanied by reversible changes in form and size, which may change the volume and appearance of the trunks or stems very markedly. The repletion of the water balance necessitates reversible changes in form, and volume, which may or may not be accompanied by irreversible additions, due to growth or morphogenetic changes. Some measurements of the bodies of massive cacti are seen to be influenced by insolation and by temperature.

Practically all of the species examined would be capable of endurance of an entire year in the open although the water supply were cut off. Not all of the individuals might survive, but some would. Slight growth of the trunk was seen in desiccated individuals of the bisnaga, but none in the sahuaro. Many individuals may be encountered in the open which show no indications of growth during the previous year, suggesting a lack of moisture. It is notable that even very much desiccated cacti which do not display growth of the succulent stems by reason of the depleted water supply may still send out roots.

The floras of arid regions are so rich in specialized forms that the conclusions seem justifiable that these types bear some sort of adaptation or fitness by which they have survived under the conditions presented. They may be readily put into two general groups: The spinose trees, shrubs, and herbs, and the succulents. The spinose forms are those in which the shoot shows the effects of an inherited atrophy of its members and a reduction of its surfaces. The result of such reduction shows narrow leaves, short pointed branches and short axes, these changes also being accompanied by an induration of the epidermal surfaces.

Many of these changes are of the same character as those produced when a plant from a moist region is grown under arid conditions, and the inference that these plants have come about by such inherited variation, is generally allowed to pass in botanical writings. The fact that many features of desert plants could not be brought about by such direct causal action, however, suggests caution in the matter, and that the origination of these forms is not capable of any simple explanation or interpretation, the chief difficulty being experienced in the explanation of the fact that a high evaporating action of the air of a habitat acts directly upon organs, and also upon the organism as a whole in a manner which may be directly antagonistic as far as morphogenic action is concerned.

The reduction of the members of the shoot and the induration of the surfaces may be regarded as the more primitive or initial modification in connection with desert conditions, and the enlargement or increase of tissues accommodating a large water balance as a secondary or consequent change of a more highly specialized character. Morphological alterations of the first named kind are discernible in plants inhabiting not only arid regions, but all localities in which the evaporating action of the air overbalances the available absorptive capacity of the vegetation.

The habit of accumulation of a large water balance affects some forms in which the reduction of the shoot has been carried to its greatest extent, and the forms displaying both modifications, such as the massive euphorbias and cacti, constitute the most pronounced types of desert vegetation. It is to be seen, however, that succulency is manifested by many plants, in which the primitive xerophytic modifications have not been extensive, and a water balance is carried in roots, stems, leaves, and special organs. The inference seems a fair one, therefore, that succulency is not the result of the simple causes leading to xerophytism.

A review of the conditions connected with the existence and distribution of succulents shows that they are abundant in northern and southern Africa, in certain deserts in South America, and are especially numerous in the arid regions of western and southern North America, reaching a maximum development as to size and number of species in the elevated basins and boisons of southern Mexico where several species of great tree cacti are prominent in the landscape. The regions characterized by succulents have a soil often rich in lime in which the precipitation is received in regularly recurring seasons. Cacti and crassulaceæ may thus be found down to the limit of the spring tides in the north temperate zone, while a few of these and other succulents occur far north in rain forests and very cold regions. An analysis of the conditions mentioned is not to be allowed to account for succulency, however, since one group of plants showing the capacity for accumulation of water, the halophytes, inhabit saline shores and soils around the world and through a wide range of latitudes. The only invariable conditions attendant upon the development of succulents seem to be the existence of an abundant supply of moisture in the soil or substratum during certain seasons and the presence of solutions of high osmotic activity in contact with the absorbent organs. Some halophytes occur in localities in which the soil contains only solutions of high concentration, while in other cases it may be subject to a wide range of variation by floods and tides.

An examination of the chemistry of these forms might probably lead to results of value in the interpretation of their development. The cacti of the Tucson region, and probably all of these forms, are rich in calcium carried in solution in the sap as an accident of its occurrence in abundance in the soil. The sap shows a high degree of osmotic activity, ranging from 5 to 12 atmospheres in various species in a state of maximum turgidity, to perhaps twice this pressure when the water balance is depleted. Furthermore, these plants, especially the halophytes, are known to be capable of an accommodative reaction by which the osmotic pressure may be automatically increased in response to the increased concentration of the soil solutions.

The sap of succulents is characterized by a high degree of acidity which seems to be least in Echinocactus and greatest in *Opuntia versicolor* in the forms examined. This acidity results from a modification of the photosynthetic processes and hence is not directly connected with the state of the water balance, although it is probable that some slight concentration or heightening of the acidity might follow desiccation.

The two recognized characteristics of succulents, the high osmotic activity and the modified photosynthesis resulting in great acidity, are not sufficient to explain their occurrence and development in deserts and saline situations, and it is evident that a more extensive investigation of their chemistry must be made before an adequate interpretation of their origination may be attempted.

Construction work was recently begun on the first of two 25,000-kilowatt hydro-electric generating stations on the tributaries to the Doce River, in Brazil, which will furnish energy for an electric railway, 400 miles in length, between Victoria and Itabira, in the State of Minas Geraes. The region penetrated by the new electric railway is a mining country producing large quantities of iron ore, the transportation of which to the coast will be the principal business of the new road. In building the road about 250 miles of existing narrow-gage road bed will be utilized, the track being converted to standard gage.

A NEW RECORD IN TELEPHOTOGRAPHY.

BY ARTHUR E. JOERIN.

A STARTLING improvement has been made recently in the art of telephotography, which will be of particular interest in connection with an illustrated article on the telephoto camera, in this journal of March 26, 1910. What has been used generally in order to take impressions of things far remote was a teleobjective which was attached to the ordinary camera. This worked fairly well if pictures had to be taken—such as buildings, landscape, etc. No snapshot picture can be taken with such a teleobjective as the latter is too weak, that is to say, too much light is absorbed by the various lenses of the old combination.

In this present invention application is made of a single extremely long-focused lens. The light rays are twice reflected in the camera by means of mirrors. If we were to use such a lens with an ordinary camera we would have to make it about 5 feet long, and its weight would be such as to make such a camera quite useless for the purpose of being carried about.

Our diagram shows the arrangement of the mirrors and the plates as well as the position of the objective. *O* is the lens; the rays passing through the lens are reflected from the mirror *M* to the mirror *M'*, and from there to the ground glass *P*. With this arrangement it is possible to reduce the size of the camera to less than one-third of the length which it would otherwise occupy; thus, this camera of 16 inches in length sufficing for a lens of 48 inches focus. Hence, we have a practical camera for the private, the professional and the military man.

The uses of such a telephotographing camera are manifold and include all branches and cases of cameras where snapshots cannot be taken ordinarily. The want of luminosity of the ordinary teleobjective is not to be contested since it gives an enlargement of the ordinary view and not a view large in itself, which renders impossible the taking of instantaneous views. There is, therefore, no loss of light because of the enlargement. It is thus possible with such an arrangement as we just have been referring to, to obtain very sharp and brilliant instantaneous views with great ease, the sharpness of the negative being such that it is possible to enlarge up to ten diameters.

The following are a few of the results of such a telephotographing camera. A reporter can photograph individuals without their knowledge.

The mountain climber can be followed in all his perilous passages by the photographer comfortably installed on the hotel balcony. (See illustrations, where one view is taken with an ordinary camera, and another where the same view is taken with the telephoto camera.)

An officer of the army can observe the positions and register important movements, and *vice versa*, a balloon may be photographed when high up in the air, and it will then be possible to recognize the passengers.

The scientist can fix on a sensitive plate the physical phenomena visible on the extreme horizon, such as mirages, and those that cannot be approached without danger, such as volcanic eruptions or inaccessible mountains.

The officer of the navy can take pictures of the battleships far remote, take reliefs of the coast which could never be secured unless with a snapshot, or a fisherboat can be photographed, in which the persons are undistinguishable with the naked eye. By utilizing the telephoto apparatus with its mirrors and a lens of short focus, direct enlargements can be made and microphotographs can be obtained by placing the object to be photographed at a distance of ten or twenty centimeters (3.94 to 7.87 inches) from the lens. This is of great value, for instance, to the scientist who wants to explain to his students at a university certain functions of animal or vegetable life, and who is then enabled to draw as many prints as he wishes from such a telephotographed plate.

The telephoto as a microscope.—An excellent microscope is obtained by employing it in the same manner as for taking micro-photographs and substituting an eye-piece for the ground glass.

The telephoto as a telescope.—An explorer does not need a special telescope, but can use his camera for the purpose by simply replacing the ground glass by a board into which is fitted the terrestrial eye-piece.

One illustration shows the ingenious inventor, Mr. Vautier, with his telephoto camera, at Geneva. It was he who conceived the idea and then worked it out with Mr. Schaer into a new system which will be able among its other accomplishments to do what has never been satisfactorily executed—to photograph scenes and objects from great heights at speeds attainable by present and future aeroplanes. Both Mr. Vautier and Mr. Schaer are of Swiss nationality and are residents of the city of Geneva.

VIEW OF MOUNTAIN CLIMBERS TAKEN FROM HOTEL BALCONY WITH ORDINARY CAMERA.

VIEW OF MOUNTAIN CLIMBERS TAKEN FROM SAME HOTEL BALCONY WITH THE TELEPHOTO CAMERA.
THE INVENTOR AND HIS TELEPHOTO CAMERA. DIAGRAM SHOWING ARRANGEMENT OF MIRRORS AND PLATES AND POSITION OF OBJECTIVE.

A NEW RECORD IN TELEPHOTOGRAPHY.

EIFFEL'S EXPERIMENTS.

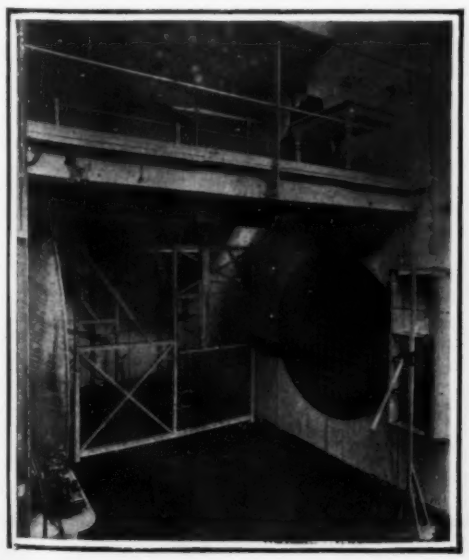
THE EIFFEL AERODYNAMOMETRIC INSTALLATION.

THE problem of procuring accurate data concerning wind pressures has been occupying for many years the attention of M. Gustave Eiffel, who in 1903 began his series of experiments with an apparatus installed on the Tour Eiffel. From the first platform of the tower was suspended a steel cable which thickened out toward its lower end. The apparatus was carried on a frame with two powerful vertical leaf springs fixed to the halves of two sleeves that were thus held together with considerable pressure. Wood liners were inserted in the sleeves, so that when the apparatus reached the end of the cylindrical part of the cable the conical section wedged out the sleeves against the pressure of the springs and thus exerted an effective braking effort on the apparatus. The frame carried a recording drum rotated by a worm shaft actuated by a friction roller on the cable. The plate to be tested was fixed to the lower part of a stem which was free to move upward against a spring, and the upper part of the stem carried a needle bearing against the drum. This heavy apparatus dropped from a height of 377 feet, and during 311 feet of its course before the braking action began, it attained a velocity of 131 feet per second. The air resistance offered to the plate expanded the accurately gaged spring and caused the registering needle to rise on the drum, which was revolving at a speed proportionate to the velocity of the apparatus, and thus the resistance was recorded for every point of the descent. This method of testing had its limitations, because it was only possible to ascertain the total resistance offered to a plane when falling at a given velocity. The experiments allowed of many interesting data being obtained, but M. Eiffel soon exhausted the possibilities of this apparatus. Although it is usually claimed that more practical results are possible by moving the surface to be tested through the air, and thereby securing conditions more approaching the normal, there are yet so many difficulties in the way of extending the line of research and making accurate observations, that M. Eiffel found himself obliged to follow the lead of Stanton, Maxim, and other experimenters who had obtained interesting results by employing stationary surfaces in a current of air. The drawback to this method of testing appeared to be that when the air was driven through a tunnel by a ventilator the walls would interfere with the parallelism of the air stream lines, or at all events there would be no means of ascertaining whether the currents created by the obstruction of the plane would not extend to the tunnel walls. In order to get accurate data the plane must be in a cylinder of air of a large enough diameter to avoid the outer stream lines from being influenced in any way by the presence of the plane. M. Eiffel therefore proposed to meet these conditions by drawing a cylinder of air through a closed room. The surface to be tested must not be too small, and the diameter of the air current should not be less than 1.50 meters (4.92 feet). It was intended to increase this diameter to 2 meters (6.56 feet) but although a cone of this dimension has been made, it is, we understand, rarely used, as the results obtained with the smaller cone are perfectly satisfactory. It will also be observed that by operating in a free column of air passing through a closed chamber it is possible to vary the manipulations and obtain readings with the greatest facility.

The installation is contained in a wood building close to the Tour Eiffel, from which the electric energy is obtained by overhead cables. On entering the building there is a large hall with, immediately in front, the air receiver and grid opening into the experimental room, to which access is obtained by a staircase. Exactly opposite the grid, on the other side of the experimental room, is an aperture of the same diameter, and behind is a Sirocco ventilator, which draws the air through the experimental room. The air passes from the ventilator through a huge wooden conduit of increasingly large diameter, which conveys it round to the front of the hall, so that the air has a circular path, and, being unaffected by the outside wind, this circular course conduces to the steadiness of the air column passing through the experimental chamber. The height of the Sirocco ventilator is 11 feet, and the diameter of the fan 5 feet 9 inches, while the total height from the ground, including the masonry bed, is 18 feet. Driven by a 50-kilowatt dynamo, with current from the Tour Eiffel, the speed of the ventilator varies from 40 to 200 revolutions per minute. With a cylinder of air 1.50 meters (4.92 feet) in diameter, the velocity may be varied from 16 feet to 65 feet per second. The air receiver or collector is built up with a framework of wood, over which is stretched a rubber fabric similar to that employed for balloons. It is supported on a frame. Its largest diameter is 3 meters (9.84 feet), or just double the aperture, and its length is 2.50 meters (8.20 feet). The object of this collector is to provide a slight compression of the air, so as to favor the regularity of the stream lines. If, however, the air were drawn through an unobstructed aperture, the horizontal column would be broken up into a mass of whirls, and in order to obtain perfectly parallel stream lines, the aperture is fitted with a grid. This grid is built up of thin sheet metal soldered like a honeycomb radiator. Each cell has a width and height of 4 inches, and a length of 10 inches. These dimensions are not based upon any recognized data, but were first adopted experimentally, and then maintained when it was found that the results were quite satisfactory. On the side opposite this grid will be seen the short cone around the opening of the tunnel, at the end of which is placed the ventilator. The distance between the two apertures is 11 feet 9 inches. At first it was noticed that the air current broke up into whirls immediately in front of the aperture on the left, and this difficulty was overcome by covering it with wire netting having meshes of 1 centimeter (0.39 inch). There is another wire netting about 3 feet in the tunnel, but we understand that one net is sufficient to insure absolute parallelism of the stream lines where they enter the tunnel. By this arrangement the air current is so perfectly cylindrical that when traveling at the highest velocity there is not the slightest draft in the experimental room.

This room is in the shape of a T, with one part parallel to the side of the building, and containing a table with the recording instruments, a switchboard, and a

THE EIFFEL AERODYNAMIC BALANCE PLACED ABOVE THE EXPERIMENT ROOM.



EXPERIMENT ROOM OF EIFFEL'S AERODYNAMIC LABORATORY.

THE INLET OF THE BLOWER.

ARRANGEMENT OF APPARATUS FOR MEASURING PRESSURES AT VARIOUS POINTS OF THE SURFACE.

THE EIFFEL AERODYNAMOMETRIC INSTALLATION.

small library of works on aero-dynamometrics. The other part contains the apparatus suspended from an upper story, on which is the weighing machine for measuring the wind pressure. The plane to be tested is attached at its center to a piece hinging on the end of a horizontal rod. It is also attached to a sliding piece capable of being fixed by a set screw a few inches along the rod, so that the plane can be turned round 180 deg., and fixed in any position. The horizontal rod is clamped in a sleeve at the bottom end of a vertical cast steel rod contained in a copper casing of larger diameter, and presenting a beveled edge in the axis of the stream lines, so as to offer the least possible resistance. The vertical rod is bolted to the platform of the weighing machine, which is carried on two sets of knife edges, one set being turned downward and the other upward. This is necessary for measuring the pressure when the plane is inclined up or down. The platform is made to rest on one or other of the knife edges by shortening or lengthening the rod from the platform to the cross beam by means of a cam, and when not in use the platform is raised to bring the knife edges out of contact with the grooves by a lever with a counterweight. This weighing machine, which was specially constructed for the installation, is sensitive to half a gramme.

When a plane is to be tested it is secured to the horizontal rod in the manner already described. Before the air current is passed through the experimental room the equilibrium is obtained by weighting the balance with the knife edges alternately in their grooves. The room is then traversed by air at a given velocity, which is determined by the speed of the ventilator regulated by the rheostat. The velocity is gaged by a manometer communicating between the air current and the still atmosphere of the outer shed, and also by a Pitot tube placed in the current and connected with a manometer, which also communicates with the still air. The results have been further verified by various anemometers, and the differences between the two are

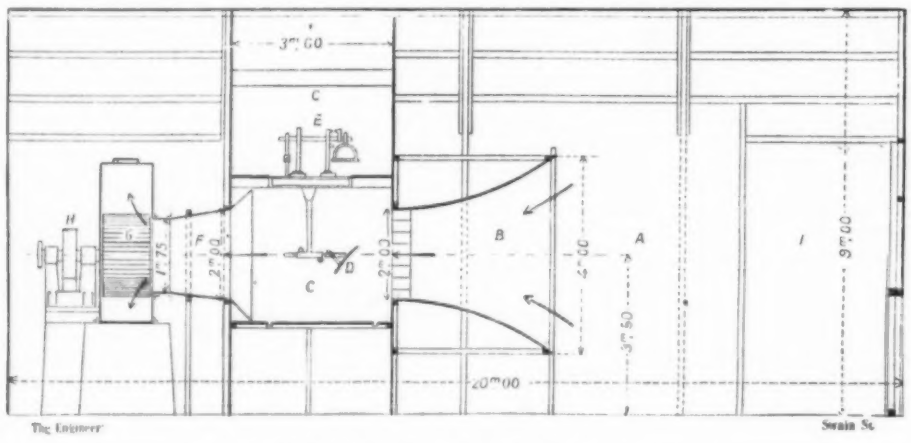


DIAGRAM SHOWING GENERAL PLAN OF THE INSTALLATION.

so small as to be inappreciable from the point of view of general results. Having ascertained the air velocity, the balance is again weighted with the knife edges in contact first on one side and then on the other and the plane is then turned round 180 deg., when the equilibrium is effected on the corresponding knife edges. These operations provide three equations for determining the total pressure, the direction, and the center of pressure. Another method of determining the center of pressure consists in placing the plane vertically between the points of two rods, the ends of the plane being drilled with holes, so that it may be held in any position. The plane is secured by a clip on the lower rod, to which is fixed a circular plate of wood with the angles marked on the edge and corresponding with marks on the fixed frame. When exposed to the air current the plane pivots round more or less, according to its curvature, and the angle is read off to give the center of pressure. This method might be expected to lack precision, but the results agree with those provided by the weighing machine.

For ascertaining the wind pressure at different parts of the plane the instruments employed are a Pitot tube and a Schultze micromanometer. It is used in conjunction with a frame which slides on rails to allow of its being brought in front of the aperture. The plate to be tested is held at any desired inclination by wires. The plate is drilled with a number of holes, which are filled by screws flush with the surface. At the point where it is desired to ascertain the pressure the screw is replaced by a threaded plug drilled with a hole 0.5 millimeter (0.0196 inch) diameter. On the side of the plate subjected to the wind pressure the plug is flush with the surface, and on the other it carries a rubber tube connected with the micromanometer. The pressure can thus be obtained at any point on either side of the plate. Highly interesting data have been obtained with this apparatus, and as showing the accuracy of the method it may be stated that the addition of the pressures obtained over the surface of a plate corresponds with the total pressure indicated by the weighbridge. We have thus seen that the installation enables the experimenter to ascertain the total pressure, the center of pressure, and the pressure at any given point on either side of the plate. Another valuable factor is the disturbance of the air stream lines caused by the presence of the plate. This is ascertained by attaching light filaments to the plate or to fine wires, and by observing their movements it is possible to sketch plans of the air whirls around and behind the plate.

It is sometimes argued that experiments with a fixed surface in a current of air can have little practical result from the point of view of aviation, for the reason that these conditions are contrary to those that govern the flight of aeroplanes. The experiments are carried out under one of many conditions, and this one is only met with when the aeroplane is at a standstill against the wind. It is obvious, however, that this one condition constitutes the basic principle of flight, and no other factor can be introduced beyond providing various devices for giving stability to the machines. Confirmation of this is seen in the fact that the Eiffel tests have demonstrated that the best compromise between lift and resistance lies in a flattened curve similar to that adopted by certain aeroplane makers after years of costly experiment. The subject is even now scarcely more than touched upon, but the investigations already carried out are laying the foundation for the scientific construction of aeroplanes, when problems that at present seem scarcely capable of solution will probably be solved.—The Engineer.

The address to the Educational Science Section of the British Association for the Advancement of Science, by Principal H. A. Miers, M.A., D.Sc., F.R.S., was long and somewhat pessimistic, arriving at the following conclusions: The acquisition of knowledge and the training of the mind are two inseparable aims of education, and yet it often appears difficult to provide adequately for the one without neglecting the other. If childhood is the time when systematic training is most desirable, it is also the time when knowledge is most easily acquired; if early manhood is the time when special knowledge must be sought, it is also the time when training for the special business of life is necessary. To withdraw from the child the opportunities of absorbing knowledge may be as harmful as it is unnatural; to turn a young man or young woman loose into a profession without proper preparation is cruel, and may be disastrous. And so we get the battle of syllabus, time-table, scholarships, examinations, professional training, technical instruction, under all of which lies the disturbing distinction between training and knowledge. But, if we inquire further into these matters, I think we shall find that the fundamental question is to a large extent one of responsibility. Left to himself, a boy or a man will acquire a knowledge of the things which interest him, even though they be only the arts of a pickpocket, and will obtain a training from experience such as no school or college can give. If education is to achieve the great purpose of interesting and instructing him while young in the right objects, and also of training him for the proper business of his life before it is too late, is it not mainly a question of deciding when and how far to take for him, or to leave to him, the responsibility of what he is to learn, and how he is to learn it? If the teacher bears the responsibility during the period of school training, should not the student have a large share of the responsibility in the quest of knowledge at the university? Now, it is of the essence of responsibility that there should be something sudden and unexpected about it. If, before putting a young man into a position of trust, you lead him through a kindergarten preparation for it, in which he plays with the semblance before being admitted to the reality, if you teach him first all the rules and regulations which should prevent him from making a mistake, you will effectually smother his independence and stifle his initiative. But plunge him into a new experience and make him feel the responsibility of his position, and you will give him the impulse to learn his new duties and the opportunity to show his real powers. It is because I feel that this sudden entrance into an environment of new responsibility is so necessary that I would regard with suspicion any attempt to provide a gradual transition between school and university methods. In matters of discipline and self-control it is possible and advisable to place responsibility upon school children; in intellectual matters it is not advisable, except for the few who are matured beyond their years. It is, therefore, all the more necessary that this should be done at the moment when they enter the university. This should be the moment of which Emerson says: "There is a time in every man's education when he arrives at the conviction that he must take himself for better or worse as his portion; that, though the wide universe is full of good, no kernel of nourishing corn can come to him but through his toil bestowed on that plot of ground which is given him to till. The power which resides in him is new in Nature, and none but he knows what that is which he can do, nor does he know until he has tried." The spirit of independent inquiry, which should dominate all university teaching and learning, is not to be measured, as I have already said, by the number of memoirs published, but it is to be tested by the extent to which university students are engaged upon work for which they feel a responsibility. Visit the universities at the present moment, and in spite of all the admirable investigation which is being carried on, you will find the majority of students engaged in exercises in which they feel no responsibility whatever. In my opinion this indicates that for them the spirit of true university education has never been awakened. It is, after all, very largely a question of attitude of mind. Any subject of study, whether it be a scientific experiment or an historical event, or the significance of a text, is a matter of interpretation, and to approach it in the university spirit is to approach it with the question, "Is this the right interpretation?" Upon that question can be hung a whole philosophy of the subject, and from it can proceed a whole series of investigations; it embodies the true spirit of research, and it opens the door to true learning. In the hope that the attention of university teachers may be turned more fully to this aspect of their work, I have ventured to make it the subject of my address.

HOLLOW POSTS OF REINFORCED CONCRETE.

IT has long been known that reinforced concrete or cement is a very suitable material for posts of all kinds. Armored concrete posts are cheap, are not subject to decay, and require practically no care or expense for maintenance. A German firm has now undertaken the manufacture of hollow posts of armored cement, which are made by a centrifugal machine. In a wooden mold, lined with sheet iron, which opens lengthwise, a series of longitudinal rods of soft steel, connected together by a helix of iron wire, is first placed. The rods are arranged to form a cylinder, and their distance from the wall of the mold is determined by the preliminary insertion of small concrete blocks. After the rods have been placed in position, the mold is partially filled with a mixture of 1 to 3 cement mortar, to which a quantity of fibrous asbestos is added as a binder. The mold is then placed in a machine, which consists essentially of an automatically centered tube, which is rotated and guided by wheels mounted on three surrounding parallel axes. By this means the mold is caused to rotate at the rate of 500 to 1,000 revolutions per minute. The plastic concrete is thrown by centrifugal force against the wall of the molds, and the iron rods are imbedded in it. The centrifugal force is so great as to produce an actual compression of the hollow cylinder of armored concrete which is thus formed, and to expel much of the water which it contains. The rotation is continued from 10 to 15 minutes, according to the thickness of the shell of concrete. The mold is then removed from the machine, but is not opened until the concrete has become permanently set, which takes place in from 12 to 24 hours. After the post has been removed from the mold it is buried in wet sand, where it is allowed to harden slowly for three or four weeks. A varying thickness can be given to the shell of concrete by inclining the mold during the rotation, as the plastic mass always tends to flow toward the lowest point. These posts are made in various lengths up to 46 feet. Their diameters range from 6 to 15 inches, and the thickness of the concrete wall from 1.2 to 3.6 inches. The posts are very strong and elastic.

ATOMIC WEIGHTS—AN HISTORICAL SKETCH.*

BY JOSEPH SAMUEL HEPBURN, A.M., M.S.

[THIS paper reviews the fundamental laws underlying atomic weight determinations. A sketch is given of the work of Dalton, Berzelius and Stas upon these constants of nature. A description is given of the schools of chemists which have carried out atomic weight determinations at the University of Pennsylvania under E. F. Smith, and at Harvard University under T. W. Richards.]

At the beginning of the nineteenth century, John Dalton[1] applied the ancient Greek philosophical theory of atoms—the theory of Leucippus and Democritos—as an explanation of his own laws of definite and multiple proportions, and thus founded the chemical atomic theory. Dalton then determined the "relative" or atomic weights of the elements; in his "New System of Chemical Philosophy," Dalton took hydrogen as the unit with which he compared the other elements. He did not distinguish between atoms and molecules, hence his table contains atomic weights for water, ammonia and other compounds. Moreover Dalton had no means for ascertaining the number of atoms in a molecule, so he assumed that the atom (our molecule) of water consists of one atom of hydrogen and one atom of oxygen, whence the atomic weight of oxygen is given as 7, less than one-half of our value 16.

The study of atomic weights was aided greatly by the discovery of certain laws. In 1808 Gay Lussac and Humboldt deduced the law of combination by volume of gases. "When two or more gaseous substances combine to form a gaseous compound, the volumes of the individual constituents as well as their sum bear a simple relation to the volume of the compound,"[2] provided that the gases be under the same conditions of temperature and pressure. This law and the laws of Boyle and Charles have been used by Avogadro and Ampère,[3] and, later on, by Canizzaro as the basis of the molecular theory.

In 1819 Dulong and Petit announced the law of specific heats; the product of the specific heat of an element times its atomic weight always gives approximately the same constant 6.25, i. e., all the elements have approximately the same atomic heat. In 1831 Neumann and Regnault discovered that the molecular heat of a compound is a multiple of the atomic heat directly proportional to the number of atoms in the molecule, e. g., lead chloride PbCl, contains 3 atoms in its molecule, and has a molecular heat of 18.45, about three times 6.25.

Mitscherlich deduced the law of isomorphism in 1819. "The same number of atoms combined in the same manner produce the same crystalline form, the latter being independent of the chemical nature of the atoms, and determined solely by their number and arrangement."[4] However barium permanganate and sodium sulphate are isomorphous in the sense that they possess the same crystalline form, yet they differ from each other in respect to the number of atoms in the molecule. Kopp[5] has found that compounds which have the same number of atoms, arranged in the same manner in the molecule and possessing the same crystalline form—isomorphous compounds according to Mitscherlich—are characterized by the property of forming overgrowths, e. g., a crystal of one alum will grow in the solution of another alum.

Within recent years, the Periodic Law of Lothar Meyer and Mendelejeff[6] has been helpful in determining the correct values of atomic weights. This law states that the properties of the elements are periodic functions of their atomic weights.

Berzelius devoted his life to atomic weight work; he made use of the laws of isomorphism, specific heats, and combination of gases by volume, and carried out analyses and syntheses without number; his work on atomic weights extended to many elements, including metals, non-metals and rare earths. As a standard atomic weight, Berzelius took oxygen equal to 100. His first table of atomic weights appeared in 1818; a revised table, which took into consideration the newly discovered laws, was issued in 1826. Many of the determinations of Berzelius, calculated to oxygen equals 16, compare favorably with the results of recent investigators.

The next great investigator to devote his life to atomic weight research was Jean Servais Stas, whose first work on the atomic weight of carbon appeared in 1841. His work on silver, sodium, potassium, lithium, lead, chlorine, bromine, iodine, sulphur, nitrogen and oxygen, is classic. Stas was exceedingly careful in all his work, yet was guilty of errors in manipulation; for instance, he would drop dry sodium chloride into silver nitrate solution, and yet expect to obtain a precipitate of pure silver chloride free from occluded or included sodium chloride. In his earlier work, he neglected the solubility of silver chloride in water. In his investigations, Stas referred the halogens to silver. The task was undertaken to test the truth of Prout's hypothesis that the atomic weights of all the elements are simple multiples of hydrogen equal to one. Stas decided that this hypothesis is without foundation.

Stas died in 1890; the work on atomic weights has been continued in Europe by such men as Guye and Gutbier and in America by Keiser, J. P. Cooke, Mallet, E. F. Smith, and T. W. Richards.

During recent years a conflict has waged among chemists concerning the standards for atomic weights. A few chemists led by Lothar Meyer have taken hydrogen equal to 1. The greater number of chemists have used oxygen equal to 16. Few of the elements form compounds with hydrogen and the ratio of an element *A* to hydrogen can usually be determined only by multiplying the ratio of *A* to a second element *B*, which most frequently is oxygen, by the ratio of *B* to hydrogen. Now the ratio of oxygen to hydrogen has been determined by various investigators and cannot be regarded as a fixed value. All the elements save fluorine and the members of the argon-helium group form oxides and hence allow a direct comparison between oxygen and the elements. Moreover if the ratio of an element to some element other than oxygen (say to silver or chlorine) be determined, the ratio of this second element to oxygen has been definitely determined. Oxygen equal to 16.00 has been accepted by the International Committee on Atomic Weights as the standard, and the column referred to hydrogen equal to 1 has been dropped from their reports since 1906.[7] However the United States Pharmacopœia still retains hydrogen equal to 1,000 as the standard.[8]

A new method for the determination of atomic weights was introduced by Smith and Maas[9] in a paper "Uber das Atomgewicht von Molybdán." They heated a known weight of anhydrous sodium molybdate in a stream of hydrogen chloride gas, weighed the residual sodium chloride and calculated the atomic weight of molybdenum. This work has been continued by E. F. Smith and his pupils at the University of Pennsylvania.

Hibbs[10] passed hydrogen chloride gas over heated potassium nitrate, weighed the residual potassium chloride and obtained the atomic weight of nitrogen. Sodium nitrate was treated in the same way for the same purpose. Sodium pyroarseniate, treated in this way, gave a value for the atomic weight of arsenic.

Lenher[11] treated silver selenite with hydrogen chloride gas, weighed the silver chloride formed, reduced the latter in hydrogen, weighed the metallic silver and thus obtained two values for the atomic weight of selenium.

Ebaugh[12] treated silver orthoarseniate with hydrogen chloride gas, weighed the silver chloride and then reduced the latter to metallic silver, which was weighed. This gave two values for the atomic weight of arsenic. Two more values were obtained by passing hydrogen chloride gas and hydrogen bromide gas over lead orthoarseniate, and weighing the residual lead chloride and lead bromide.

Friend and Smith[13] determined the atomic weight of antimony by treating potassium antimonyl tartrate with gaseous hydrogen chloride, and weighing the residual potassium chloride.

Smith and his pupils have devoted much time to the determination of the atomic weight of tungsten. In 1899 Hardin[14] stated that "so far as known, there is no perfectly reliable method for the determination of this constant. The method of reduction and oxidation is probably more accurate than any of the other methods which have been employed. The results obtained by it vary about one unit, and even more in exceptional cases." The story of the determination of the atomic weight of this element is a tale of the gradual elimination of impurities. Smith and Pennington took precautions to remove molybdic acid from their tungstic acid.[15] Schneider had noticed a very slight residue when purified tungstic acid was dissolved in aqueous potassium hydroxide, but neglected it. Taylor[16] found that purified tungstic acid, when treated with aqueous sodium carbonate, gave a white flocculent residue, which turned reddish-brown after standing in contact with the sodium carbonate solution for several hours. Exner and Smith[17] prepared ammonium paratungstate from wolframite of Lawrence County, South Dakota. In the mother liquor they isolated ammonium vanadico-phosphotungstate.[18] Hardin[19] had proved that tungstic acid obtained by ignition of ammonium tungstate contains nitrogen. Wyman[20] had experienced great difficulty in obtaining complete solution of tungstic acid in ammonia. Exner and Smith now examined the insoluble residues of Wyman and found them to contain ammonia and chlorine. To eliminate these impurities from tungstic acid, dry ammonium tungstate was thrown into pure boiling nitric acid, to which a small quantity of pure hydrochloric acid was added from time to time, and was digested for several hours. The tungstic acid thus obtained was thoroughly washed, suspended in water and dissolved by means of ammonia gas, in order to obtain ammonium paratungstate. This salt was submitted to fractional crystallization, and a product was finally obtained which did not give a precipitate on standing over night with sodium carbonate solution. Therefore this salt was free from those impurities which the investigators had striven to eliminate. The pure ammonium paratungstate was treated in porcelain vessels with nitric acid and a little hydrochloric acid, evaporated to dryness and ignited in order to obtain tungstic acid, which was reduced to metallic tungsten by the method of Hardin.[21] The tungsten metal was heated in chlorine gas to obtain tungsten hexachloride. A weighed quantity of the hexachloride was converted into the trioxide by means of water, aided by a very slight quantity of nitric acid. From the ratio of the trioxide and hexachloride, the atomic weight 184.04 was obtained for tungsten.

Hardin has applied electro-analysis in the determination of the atomic weights of mercury, silver and cadmium.[22]

A paper on atomic weights would be incomplete without reference to the work of T. W. Richards of Harvard, and his pupils. Their work, which is found chiefly in the Proceedings of the American Academy of Arts and Sciences, covers the atomic weights of copper, barium, strontium, zinc, magnesium, nickel, cobalt, iron, uranium, calcium, cæsium, potassium, sodium, iodine, chlorine, sulphur, arsenic, nitrogen, silver and chromium.

Richards and the Harvard school have worked chiefly on the halides of the metals, changing them to silver halide which is weighed. In connection with this work, the nephelometer was invented to measure the opalescence of silver chloride solution. A perfected form of nephelometer has been described by Richards and Wells.[23] Elaborate apparatus for fusing and bottling pure salts and metallic silver for atomic weight work had been devised by Richards and Parker.[24] "A Revision of the Atomic Weights of Sodium and Chlorine,"[25] by Richards and Wells, shows in detail the manner in which Richards and his pupils attack a problem of this kind.

We thus see that the masters of the science for over a century have devoted their best efforts to determining these constants of nature. With the introduction of new and more accurate methods of analysis and of new methods for the purification of reagents, the old rule of Berzelius, which calls for the use of pure reagents and a simple method of analysis, is found to give accurate and concordant results.

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* Journal of the Franklin Institute.

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[11] Lenher: University of Pennsylvania Thesis 1898.

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[14] Hardin: Journal of the American Chemical Society, 1899, xxi, 1026.

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[16] Taylor: University of Pennsylvania Thesis 1901.

[17] Smith and Exner: Proceedings of the American Philosophical Society, 1904, xliii, 123.

[18] Smith and Exner: Journal of the American Chemical Society, 1902, xxiv, 573.

[19] Hardin: Journal of the American Chemical Society, 1897, xix, 675.

[20] Wyman: University of Pennsylvania Thesis 1902.

[21] Hardin: Journal of the American Chemical Society, 1897, xix, 667.

[22] Hardin: University of Pennsylvania Thesis 1896.

[23] Richards and Wells: American Chemical Journal, 1904, xxxi, 235; Wells: American Chemical Journal, 1906, xxxv, 99.

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A 1,000-MILE WIRELESS STATION.—IV.*

HOW TO CONSTRUCT THE RECEIVING STATION.

BY EDWARD H. GUILFORD.

Concluded from Supplement No. 1815, Page 247.

THE diagram for wiring the various instruments described in the preceding articles of this series is shown in Fig. 1. It will be readily seen that when the double throw triple knife switch *TS* is in one position the double slide tuning coil is in the circuit, and with the switch in the other position, the receiving transformer may be used. This is probably the most popular of all the systems used by amateurs. Figs. 2, 3, 4, and 5

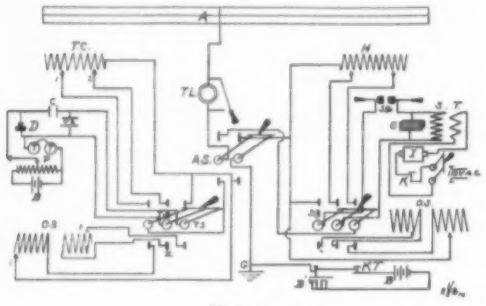


FIG. 1.

A, aerial; TC, tuning coil; C, fixed condenser; VC, variable condenser; D, detector; T, telephones; P, potentiometer; B, battery; OS, oscillation transformer; TS and SS, triple knife double throw switch; AS, aerial switch; TL_0, tuning lamp; G, ground; H, helix; SG, spark gap; ST, step up transformer; C, condenser; I, impedance; K, sending key; KT, testing key; B', buzzer.

give the separate wiring diagrams of which Fig. 1 is a combination.

The use of a potentiometer or battery depends upon the kind of detector used. Silicon, ferron or molybdenite require no batteries, and consequently no potentiometers, hence to use the circuits shown in Figs. 4 and 5, in connection with either of the last-named detectors, the telephone should be bridged directly around the fixed condenser, the potentiometer and battery being discarded. That is, one end of the telephone cord is connected to one side of the condenser while the remaining end of the telephone cord is connected to the other side of the condenser. If either a pericon or an electrolytic detector is used, a battery and potentiometer should be used to secure the best results. The circuits of Figs. 4 and 5 are suitable for use with the above detectors.

The transmitting circuit, shown in Fig. 2, is one commonly used in the majority of stations. Where one desires to cover a wide range of wave-lengths the transmitting oscillation transformer is more efficient than the helix. Fig. 1 shows a transmitting system using either helix or oscillation transformer. This is an ideal circuit for an amateur's use for this reason: A station can be called with the *helix* in the circuit, an ordinary wave-length being used, say around 500 meters (1,640.8 feet). When communication is established the operator can switch over to the *oscillation transformer*, which should tune the wave to about 1,000 meters (3,280.8 feet). The station using this transmitting system may then talk for hours without disturbing nearby stations, for few stations "listen in" with their receiving instruments set to receive waves

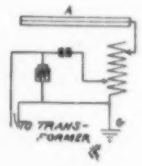


FIG. 2.

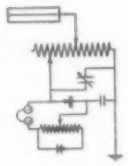


FIG. 4.

as long as 1,000 meters. Fig. 3 shows a transmitting circuit using an oscillation transformer.

When sensitive detectors, such as pericon, electrolytic or silicon are used in a station having powerful transmitting instruments, they have a tendency to "blow out," i. e., the contact in the detector becomes less sensitive, and some means must be provided to protect them from this trouble, otherwise a readjustment is necessary each time the transmitting instruments are used. There are several ways of doing this, one of the best of which is to use a single throw double knife switch to disconnect the two wires connected to the detector. Another way is to short-circuit the detector, while a third means of accomplishing this end where the detector must be placed very near the spark gap, as in a portable set, is to inclose the detector in a metal-lined box, the metal lining being grounded. While transmitting, the wires leading to the detector are disconnected by means of a switch.

Sometimes it will be noticed that an excessive humming can be heard in the telephones, perhaps so loud that it will drown out signals which are otherwise plainly heard. This humming is sometimes due to arc lights, but more often occurs because the wireless station is in the immediate vicinity of an Edison light circuit. The hum may be tuned out by using the oscillation transformer, or by grounding the free end of the tuning coil (marked *S* in Fig. 1). Another and still easier means of overcoming the difficulty where electric lights are used in the same house with the wireless station is to disconnect the feed wires just as they enter the house. A switch will always be found for this purpose on the board which carries the meter and the fuse blocks.

When the instruments are all connected up the operator is ready to receive. Assuming that the wiring diagram of Fig. 1 is used, first see that a battery current is flowing through the detector. A good test for this is to open and close the battery circuit which should cause a clicking in the telephone; next see that the aerial switch *AS* is in the receiving position and that the switch *TS* is thrown so that the tuning coil is in the circuit. If everything is right a click should be heard at intervals in the telephone, which is caused by the discharge of a minute quantity of electricity which collects in the aerial system. This discharge, by the way, is interesting and is worthy of a few words. Before a thunder shower it may be heard quite frequently, the discharges sometimes occurring so rapidly that they interfere very much with receiving. The

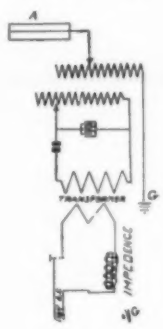


FIG. 3.

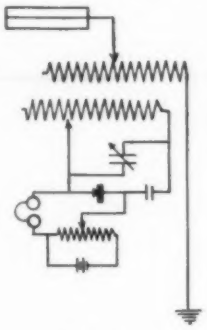


FIG. 5.

approach of a thunder shower may be readily foretold by their presence. An approaching change of temperature, nearly always from a lower to a higher degree, may also be foretold by "listening in" at the receiving instruments. This would seem to prove that small charges of electricity float around on minute particles of moisture and dust, and coming in contact with the aerial wires, collect there, the wires of course having some capacity, although perhaps not very much. When a sufficient charge has collected in the aerial wires, the resistance through the receiving instruments is overcome, the electricity passing from the aerial to the ground, and a consequent click is heard in the telephone. If the clicking caused by the discharge from the aerial is heard, it signifies that both the aerial and the ground are connected to the receiving instruments. If no click is heard, examine the wiring and see that the antenna and the ground are correctly connected to the receiving circuits. Of course in extreme cases this discharge may not be present, but usually, especially in the summer, it is plainly heard. When the operator is assured that the aerial and the ground are correctly connected, he should look to his detector and his potentiometer. Press the test key *KT* (see Fig. 1), and adjust the detector until the resulting buzz is best heard in the telephone. Then adjust the potentiometer by sliding the contact back and forth until the strength buzz is again increased. Next adjust the variable condenser until its capacity is zero (such a position is determined by swinging the rotary plates until they are entirely without the fixed plates), and adjust the sliders of the tuning coil until No. 1 is within 10 or 12 turns of the end of the coil to which the ground is connected, and the slider marked 2 includes some 15 to 20 turns of wire. These positions of the sliders on the tuning coil are shown in Fig. 1. If now any station happens to be sending, and is within range, a series of long and short buzzes may be heard in the telephones, provided that the station is using an ordinary wave-length, say from 200 meters (656.2 feet) to 600 meters (1,968.5 feet). If such a station can be heard, a further adjustment of detector, potentiometer and sliders will usually increase the strength of the incoming signals. Suppose now, that some other station with a wave-length within the above-mentioned range begins sending. Provided that it is within range, interference will result. To cut this interference out, throw over the switch marked *TS* in Fig. 1 to the position 2, and with the coils of the oscillation transformer close together, adjust slider No. 1 so that it includes about the same number of turns of wire as slider No. 1 did on the tuning coil; also adjust slider No. 2 in the same way. Either or perhaps both stations will now be heard, but by turning the variable condenser, readjusting the sliders, or separating the coils of the oscillation transformer, the

MORSE	CONTINENTAL
A .—	.—
B —...	—...
C —.—.	—.—.
D —..	—..
E .	.
F ..—.	..—.
G ——.	——.
H	....
I ..	..
J .———	.———
K —.—	—.—
L .—..	.—..
M ——	——
N —.	—.
O ———	———
P .——.	.——.
Q ——.—	——.—
R .—.	.—.
S ...	...
T —	—
U ..—	..—
V ...—	...—
W .——	.——
X —..—	—..—
Y —.——	—.——
Z ——..	——..
PERIOD .—.—.—	PERIOD ..—.—.
INTERROGATION ..——..	INTERROGATION ..——..
1 .————	.————
2 ..———	..———
3 ...——	...——
4 ....—	....—
5	.....
6 —....	—....
7 ——...	——...
8 ———..	———..
9 ————.	————.
0 —————	—————

right station will be heard plainly while the interfering station will be entirely cut out. Of course all this manipulation of sliders and coils takes time, hence it is advisable to "pick up" the station whose sending the operator wishes to hear, while that station is still sending preliminary call letters and before the operator has started the main part of his message. With a little practice this can be readily done. If interference should happen to occur while the oscillation transformer is in the circuit the interference may be instantly thrown out by adjusting either the coupling (i. e., the distance between the primary and secondary coils of the oscillation transformer) the capacity (by rotating the variable condenser), or the inductance (by moving the sliding contacts). These rules apply equally well to the use of the doughnut transformer, the various degrees of coupling being obtained with the use of that instrument by rotating the secondary through an arc of 90 degrees.

To adjust the transmitting instruments, first see that the aerial and the ground are connected by means of the aerial switch to the sending instruments. Then, by opening the small single throw single knife switch at *TL*, connect the tuning lamp in the aerial wire. This lamp is an ordinary 110-volt, 8 candle-power electric

* Electrician and Mechanic.

light bulb, and except when the transmitting circuit is being tuned, it is left short-circuited. Adjust the length of the spark until it is of steel-blue color, and gives forth a sharp, crackling sound. Then arrange the contacts of the helix in the same relative position as shown in Fig. 1, the slider connected to the condenser including about 4 turns of wire on the helix, the slider which leads to the antenna including 10 or 12 turns. If now a long dash is sent out it will be found that the tuning lamp *TL* will light up to some degree of brilliancy. By readjusting the sliders on the helix the lamp may be brought up to its full strength, thus showing of course that the circuits are in resonance. This method of tuning by means of the lamp is a crude one at its best, and cannot compare with the method which employs a hot-wire ammeter, the use of which is recommended in all cases. Tuning by means of a hot-wire ammeter is effected in exactly the same way as with the tuning lamp. The oscillation transformer sometimes used in place of the helix is very simple to adjust. Fig. 3 shows a wiring diagram with it in the circuit. The circuits are tuned exactly the same as those employing a helix. The relative positions of the primary and secondary sliders is shown in the wiring diagram of Fig. 1.

When the sliders of the helix or the oscillation transformer are finally correctly arranged, the adjustment of the spark may sometimes be improved by increasing or decreasing its length, or by varying the amount of condenser in the circuit. A high, hissing spark indicates that the amount of condenser in the circuit is too small, while if only a deep, slow, "growling" spark can be obtained, the condenser is too large, and a section or two should be disconnected. The correct spark is one which sounds neither high nor low, but about half way between those extremes. It should be smooth and of even tone.

When the sliders and the condenser of the transmitting circuit are once fixed, the only thing which needs frequent attention is the spark. The above meager directions will perhaps give the operator a hint of what he may expect. The best teacher is, however, practice, and the usual practice is for one station to test out his spark with another station, making changes according to the directions of the operator who "listens in."

Owing to the numerous recent requests, the Morse and Continental codes are printed above. The Continental is the easier of the two, both in sending and receiving, hence it is wise to learn it first. The Morse code can be easily learned. Both codes are commonly used, the Continental being the most popular, however, with amateurs.

In conclusion, I would say, that I have attempted to give only the most essential of details, the object being to install the *idea* in the mind of the amateur, leaving the petty details to be supplied by his previous experiences. For this reason the text may be somewhat vague in places, to those who have but recently become interested in wireless.

THE ISOLATION OF AN ION.—III.*

A PRECISION MEASUREMENT OF ITS CHARGE AND THE CORRECTION OF STOKES'S LAW.

BY PROF. R. A. MILLIKAN, UNIVERSITY OF CHICAGO.

Concluded from Supplement No. 1815, page 245.

6. THE FAILURE OF STOKES'S LAW.

When the values of e, were computed as above for different drops, although each individual drop showed the same sort of consistency which was exhibited by the drop of Table I., the values of e, at first came out differently even for drops showing the same value of the velocity under gravity. This last irregularity was practically completely eliminated by blowing the drops into air which was strictly dust-free, but even then drops of different siz .s as determined by v_1 always gave consistently different values of e_1. This is illustrated by the observations shown in Tables II., III., IV., V., VI., and VII. The drops shown in Tables II. and III. were of almost exactly the same size as is seen from the closeness of the values of the two velocities under gravity, and although the field strength was in one case double that in the other the values of e_1 obtained are almost identical. Similarly Tables VI. and VII. are inserted to show the consistency which could be attained in determining the values of e_1 so long as the drops used were of the same size. On the other hand, the series of Tables II., IV., V. and VI. or III., IV., V., and VII. show conclusively that the value of e_1 obtained in this way diminishes as the velocity of the drop increases. This means of course that Stokes's law does not hold for these drops.

In order to find in just what way this law breaks down we made an extended series of observations upon drops the velocities of which varied in the extreme cases 360 fold. These velocities lay between the limits 0.0013 centimeter and 0.47 centimeter per second. Complete records of a few of these observations are given in Tables VIII., IX., X. and XI.

On account of the obvious importance of obtaining accurate readings on the larger drops, for which Stokes's law should most nearly hold, the times of fall of such drops under gravity were taken with a chronograph with as great care as possible. Also wherever it was possible, the same drop was timed by both Mr. Fletcher and myself in order to eliminate the personal equation. The degree of precision which we attained can be judged from the readings recorded in the columns headed G, in the Tables VIII., IX., X. and XI. It will be seen that we very seldom made a reading of the time interval involved in the passage of our star between the cross-hairs which differed from the mean time interval by more than one twenty-fifth of a second. Furthermore, Mr. Fletcher's and my own mean times on a given drop generally differed from each other by less than one one-hundredth of a second.

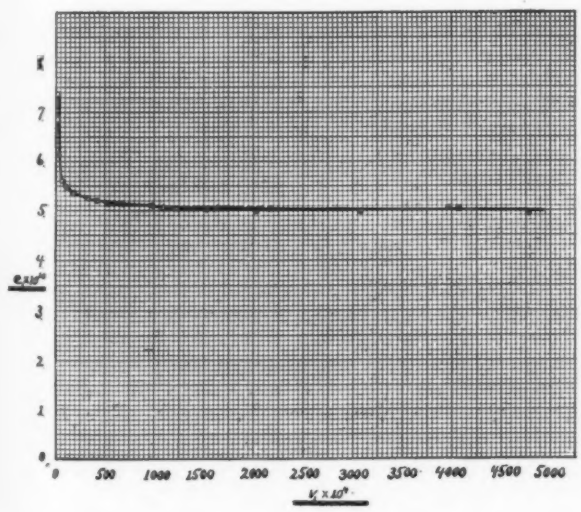
All of the times recorded under F in these tables were taken with a stop watch for the reason that in view of the way in which v_1 and v_2 enter into formula (4) and also in view of the fact that v_2 was in all these observations very much larger than v_1 no increase in the accuracy of e_1 could be obtained by the use of a chronograph in the observation on v_2.

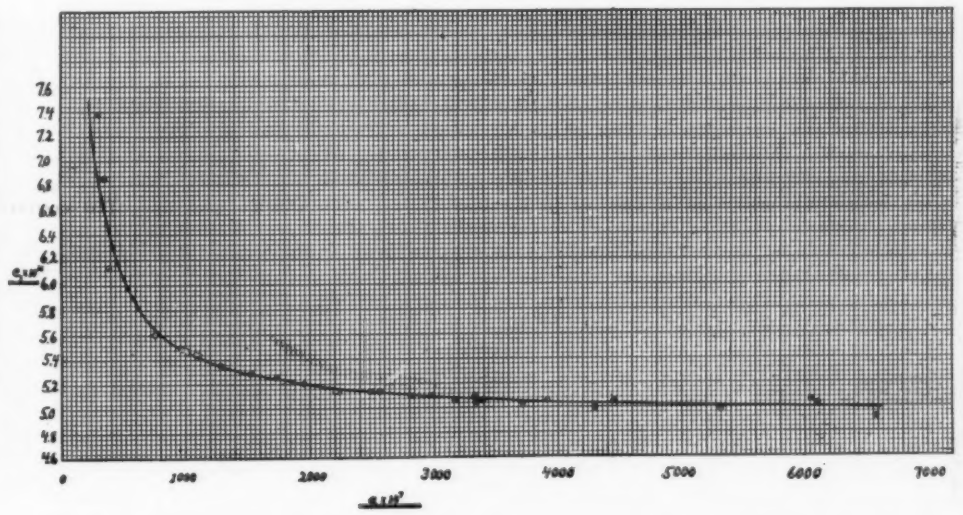
The volts were read just before and just after the observations on a given drop by dividing the bank of storage cells into eleven parts and reading the *PD* of each part by means of a 900 volts Kelvin and White electrostatic voltmeter which we calibrated with an accuracy of one-tenth of one per cent by comparing it with a Weston voltmeter which had been standardized at the Bureau of Standards.

The letter F before a reading means that it was taken by Fletcher, the letter M that it was taken by Millikan.

It will be seen from the tables that even in the case of the largest drops, which were charged with as many as 130 elementary units, the values of n are in every case unmistakably determined by the differences summarized at the bottoms of the tables. In fact, in general, even with the largest drops the relative value[1] of e_1 can be determined with an accuracy of 0.005 per cent from the differences alone. The accuracy is, of course, increased by dividing the values of e_n by n as soon as n has been found with certainty from the differences.

The readings shown in these tables are merely samples of the sort of observations which we took on between 100 and 200 drops between December, 1909, and May, 1910. The sort of consistency which we attained after we had learned how to control the evaporation of the drops, and after we had eliminated dust from the air, may be seen from Table XII, which contains the final results of our observations upon all of the drops except three studied throughout a period of forty-seven consecutive days. The three drops which have been excluded all yielded values of e_1 from two to four per cent too low to fall upon a smooth e_1 v_1 curve like that shown in Fig. 1, which is the graph of the results contained in Table XII. It is probable that these three drops corresponded not to single drops, but to two drops stuck together. Since we have never in all our study observed a drop which gave a value of e_1 appreciably above the curve of Fig. 1, and since further a sphere must have a higher rate of fall than a body of any other form whatever having the same mass and density, the hypothesis of binary drops to account for an occasional low value of e_1 is at least natural. After elementary dust we found not more than one drop in ten which was irregular. The drop shown in Table I. is perhaps the best illustration of the case under consideration which we have observed. It yields a value of e, which is four per cent too low to fall on the curve of Fig. 1. This is as large a departure from this curve as we have thus far obtained.





7. THE CORRECTION OF STOKES'S LAW.

The procedure actually adopted for correcting Stokes's law will be detailed elsewhere. The end result is this: An equation of the following form is made to replace Stokes's equation (2):

$$f = 6\pi\mu a v \left(1 + A\frac{l}{a}\right)^{-1} \quad \ldots\ldots(5)$$

or

$$V_1 = \frac{2}{9}\frac{g a^2(\sigma - p)}{\mu}\left(1 + A\frac{l}{a}\right), \quad \ldots\ldots(6)$$

in which a is the radius of the drop; l the mean free

* Paper read before the American Physical Society.

[1] Since the same value of G is used in computing all of the e 's the relative values of e_n are practically independent of the error in G.

TABLE II.

Negative Drop, No. 5.

Distance between cross hairs = 1.383 centimeters.
Temperature = 24.6° Centigrade.
Density of oil at 25° Centigrade... = 0.9041

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
	10.8	26.2	2	10.98	5.490
F = 11.9	121.0	11.9	4	21.98	5.495
	121.2	16.5	3	16.41	5.470
	120.1	16.3			
F = 26.40	120.2	26.4	2		
	119.8	67.4	1	5.495	5.495
G = **120.07**	120.1	26.6	2	1.098	
V = 9150		16.6	3	16.41	
	120.2	16.6			
F = 16.50		16.5			
	120.2	68.0	1	5.495	
F = 67.73	119.9	67.8			
		26.4		10.98	

V_1 = **0.01085** Mean e_1 (weighted) = **5.490**

TABLE III.

Negative Drop, No. 8.

Distance between cross hairs = 1.033 centimeters.
Temperature = 20° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
	88.0				
V = 35.2	88.8	95.3	2	10.98	5.490
G = **87.85**	87.8	31.0	4	21.93	5.482
F = 30.9	87.4	30.8			
	87.8	47.0	3	16.41	5.470
	87.3				

V_1 = **0.01176** Mean e_1 (weighted) = **5.482**

TABLE IV.

Negative Drop, No. 12.

Distance between cross hairs..... = 1.075 centimeters.
Temperature = 24.3° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
	53.8	49.2	4	21.46	5.365
F = 49.15	53.7	49.1			
G = **53.80**	54.0	95.2	3	16.00	5.333
V = 3880		95.5			
	54.2	96.6			
F = 95.78	53.7	95.8			

V_1 = **0.01868** Mean e_1 (weighted) = **5.349**

TABLE V.

Positive Drop, No. 15.

Distance between cross hairs..... = 1.033 centimeters.
Temperature = 20° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
	30.4	12.8	10	52.06	5.206
	30.5	17.9	8	41.61	5.201
	30.6	43.8	5	26.08	5.216
	30.2	85.9			
	30.5	85.9			
G = **30.48**	30.7	86.4			
V = 9010	30.5	85.6	4	20.84	5.210
	30.7	86.2			
F = 86.09	30.5	86.2			
		86.4			
	33.2	2550.0	3	15.55	5.183

V_1 = **0.04265** Mean e_1 (weighted) = **5.208**

TABLE VI.

Positive Drop, No. 16.

Distance between cross hairs. = 1.317 centimeters.
Temperature = 27.6° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
	24.61[4]	151.9			
	24.4	152.9			
F = 152.9	24.61	152.4	5	25.75	5.150
	24.6	153.5			
	24.4	153.9			
V = 9075	24.7	39.4	7	36.03	5.147
G = **24.57**					
	24.8	29.2			
	24.6	28.6			
F = 28.92	24.50	28.9	8	41.07	5.134
	24.59	29.0			
	24.54	16.0			
F = 15.93	24.53	16.0	11	56.25	5.114
		15.8			

V_1 = **0.05360** Mean e_1 (weighted) = **5.143**

[4] The readings carried to hundredths of a second were taken with a chronograph, the others with a stop watch. The mean "*G*" from the chronograph readings is 24.567, that from the stop watch readings 24.588.

TABLE VII.

Negative Drop, No. 17.

Distance between cross hairs..... = 1.305 centimeters.
Temperature = 26.8° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
	23.8	31.5			
	24.6	31.3	8	41.10	5.139
F = 31.33	23.4	31.2			
	23.7	43.8			
G = **23.58**	23.7	43.6			
V = 8975	23.8	44.7	7	36.09	5.156
F = 45.42	23.5	43.4			
	23.2	43.4			
F = 24.2	23.5	24.2	9	46.29	5.144

V_1 = **0.05534** Mean e_1 (weighted) = **5.145**

TABLE VIII.

Negative Drop, No. 20.

Distance between cross hairs = 1.314 centimeters.
Temperature = 23.4° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
V = 8431	M 14.87	114.7	11	56.14	5.104
F = 114.9	" 14.88	114.8			
	" 14.87	115.3			
G = **14.857**	" 14.90	64.2	12	61.20	5.100
V = 8428	" 14.85	64.8			
V = 6435	" 14.82	64.2			
	" 14.84	64.2			
V = 8423	" 14.84	117.0	11	56.12	5.102
F = 117.0	" 14.84	117.0			

V_1 = **0.08843** Mean e_1 = **5.102**

TABLE IX.

Negative Drop, No. 27.

Distance between cross hairs ..... = 1.317 centimeters.
Temperature..... = 25.2° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
V = 8793	F 8.03	48.6	28	141.78	5.063
F = 99.35	" 8.03	98.9	26	131.58	5.061
V = 87.92	" 8.08	99.8			
F = 67.05	" 8.06	67.2	27	136.34	5.050
V = 8790	" 7.96	66.9			
	" 7.98	32.7	30	151.69	
	M 7.96	32.6			
	" 8.04	27.6	31		
F = 32.66	"	32.6			
V = 8788	" 7.92	32.7	30	151.69	5.056
G = **8.013**	" 8.02	32.7			
F = 24.67		24.7	32	161.41	5.044
V = 8786	" 8.06	24.6			
		24.7			

Forced change with radium.

V = 8785	" 8.03	50.5	28	141.20	5.043
F = 68.3	" 8.01	68.2	27	136.17	5.043
V = 8784		68.4			
F = 107.15	" 8.01	107.2	26	131.05	5.040
V = 8782		107.4			

V_1 = **0.16436** Mean e_1 = **5.050**

F's mean *G* = 8.023. *M*'s mean *G* = 8.007

Differences:	e	n	e_1	Prob. Error.
141.78 − 131.58 =	10.20 ÷ 2 =		5.10	1 per cent
136.34 − 131.58 =	4.76 ÷ 1 =		4.76	2 per cent
151.69 − 136.3 =	15.35 ÷ 3 =		5.12	2 per cent
161.41 − 141.20 =	20. 0 ÷ 4 =		5.05	1 per cent
141.20 − 36.17 =	5.03 ÷ 1 =		5.03	2 per cent

Weighted mean difference = 5.03

path of the gas molecule, and *A* an undetermined constant which we obtain from our observations. It turns out that *A* is identical to within the limits of observational error (not more than 1 or 2 per cent) with the value deduced by Cunningham[5] from kinetic theory considerations, provided the *f* of his formula[6] is made equal to zero. This means that the value of *A* given by our observations is 0.815. The values of *a* in Tables XII. and XIII. are computed from (6) in which *a* is now the only unknown.

8. THE ABSOLUTE VALUE OF *e*.

Using now (6) instead of (4) to combine with (1) and denoting by *e* the absolute value of the elementary charge and by e_1 as heretofore, the value of this charge as obtained from the use of the usual form of Stokes's law—i. e., from (4)—there results at once

$$e\left(1 + A\frac{l}{a}\right)^{\frac{3}{2}} = e_1 \ldots\ldots\ldots\ldots (7)$$

Table XIII. contains the values of *e* obtained from all of the observations recorded in Table XII. except the first four and the last six. These are omitted not because their introduction would change the final value of *e*, for as a matter of fact this is not appreciably altered by including them, but solely because of the experimental errors involved in work upon either exceedingly slow or exceedingly fast drops. When the velocities are exceedingly slow residual convection currents introduce errors, and when they are exceedingly fast the time determination becomes uncertain.

The final mean value of *e* is 0.9016×10^{-10}. The probable error computed from the number of observations shown in the last column and their average divergents should be about one-tenth of one per cent. Since, however, the coefficient of viscosity of air is involved in the formula the accuracy with which *e* is known is limited by that which has been obtained in the measurement of this constant. After a prolonged and very careful study of all the data available on the viscosity of air, I have chosen as the most probable value of μ at 15°.0001785. For reasons which will be detailed elsewhere, it is thought that the error in this value is less than one-half of one per cent.

It is most interesting that the agreement between Cunningham's rational formula and our experimental results is so perfect. How perfect it is may be seen graphically from Fig. 2, in which the curve is computed from 7 under the assumption of *e*=4.9016, and

[5] Proc. Roy. Soc., 83, p. 360. [6] Cf. p. 361, *l. c.*

TABLE X.

Negative Drop.

Distance between cross hairs..... = 1.007 centimeters.
Temperature = 21.8° Centigrade.

	G Sec.	F Sec.	n	$e_n \times 10^{10}$	$e_1 \times 10^{10}$
V = 0.8845		16.88	46	332.07	
		15.0	47	238.43	
F = 15.07		14.8			
V = 0.8845		15.4			
		18.5	45	237.21	
F = 18.60		18.7			
V = 8844		18.6			
		20.6	44	222.67	
	F 4.66	27.5			
	" 4.69	27.5			
	" 4.57	27.8			
	" 4.61	27.9			
		27.9			
	" 4.66	27.7			
F = 27.73	" 4.56	27.6	42	212.70	5.064
V = 8843	" 4.61	27.7			
	" 4.65	27.6			
		27.7			
	M 4.60				
	" 4.62	28.0			
	" 4.61	27.9			
	" 4.61	33.6			
	" 4.68	33.8			
F = 33.75	" 4.61	33.8	41	207.33	5.057
V = 8841		33.7			
	" 4.64	33.7			
	" 4.62	33.9			
F = 42.55	" 4.61	42.5	40	202.28	5.057
V = 8840	" 4.61	42.6			
	" 4.64	33.8			
		34.2	41	207.30	5.055
F = 34.05		34.2			
V = 8839	" 4.66	34.0			
	" 4.67	34.8	41		
G = **4.630**		34.4			
	" 4.68	34.8			
	" 4.61	28.8	42		
F = 34.67	" 4.66	34.5	41	206.86	5.045
V = 8837	" 4.62	34.7			

Forced change with radium.

F = 59.51	F 4.58	59.4	39	196.75	5.045
V = 8836	" 4.63	59.6			
	" 4.64	60.0			
F = 44.1		44.1	40	201.60	5.041
V = 8835	" 4.64	44.0			
	" 4.63	44.2			

Forced change with radium.

F = 219.3	F 4.66	216.7	37	186.39	5.038
V = 8834	....	222.0			

Forced change with radium.

	F 4.64	35.0			
	" 4.60	35.2	41	206.59	5.039
F = 35.2	" 4.65	35.4			
V = 8833	" 4.65	35.2			
	" 4.67	44.8			
		45.2			
F = 45.00	" 4.60	45.4	40	201.30	5.033
V = 8831		45.4			
		45.5			
		35.6	41		

Forced change with radium.

		19.1			
		19.6			
		19.2			
		19.6			
		19.5			
		19.4			
F = 19.42		19.3	45	236.21	
V = 8829		19.2			
		19.7			
		19.6			
		19.3			
		19.2			
		19.7			
		19.5			

Forced change with radium.

		64.0			
F = 63.45		63.4	39	196.12	
V = 8827		63.0			
		63.4			
F = 100.2		100.0	38	191.11	
V = 8826		100.3			

V_1 = **0.2175** Mean e_1 = **5.046**

F's mean *G* = **4.629** *M*'s mean *G* = **4.632**

Differences:	e	n	e_1	Error.
196.12 − 191.11 =	5.01 ÷ 1 =		5.01	1 per cent
236.21 − 195.12 =	30.09 ÷ 6 =		5.02	1 per cent
236.21 − 201.30 =	24.11 ÷ 5 =		4.98	2 per cent
206.59 − 186.39 =	20.20 ÷ 4 =		5.04	1 per cent
201.60 − 186.39 =	15.30 ÷ 3 =		5.10	1 per cent

Mean difference (weighted) = **5.035**

TABLE XII.

No.	Velocity cm.-sec.	Radius cm.	$e_1 \times 10^{10}$	Prob. Error.
1	.001315	.0000313	7.384	6.
2	.001673	358	6.864	4.
3	.001927	386	6.142	2.5
4	.000813	255	5.695	1.5
5	.01085	967	5.490	.5
6	.01107	979	5.496	.7
7	.01164	.0001004	5.483	.4
8	.01176	1006	5.482	.4
9	.01193	1016	5.478	.8
10	.01339	1084	5.448	.5
11	.01415	1109	5.448	.4
12	.01868	1281	5.349	.5
13	.02613	1521	5.253	.5
14	.03337	1730	5.257	.5
15	.04265	1954	5.208	.5
16	.05360	2205	5.148	.4
17	.05534	2254	5.145	.5
18	.0980	2461	5.143	.7
19	.07270	2562	5.139	.5
20	.08843	2815	5.102	.3
21	.08822	2805	5.107	.4
22	.1102	3106	5.065	.4
23	.1219	3244	5.042	.5
24	.1224	3320	5.006	.5
25	.1267	3333	5.001	.5
26	.15145	3712	5.027	.5
27	.1644	3876	5.050	.5
28	.2027	4297	4.989	.7
29	.2175	4447	5.046	.4
30	.3089	5315	4.980	1.
31	.3809	6047	5.000	1.
32	.4074	6104	5.033	1.
33	.4735	6581	4.911	1.5

our experimentally determined values of e_1 are plotted about this curve, every observation contained in Table XII. being shown in the figure. Nevertheless it is to be particularly emphasized that the correctness of our final value of the elementary electrical charge is completely independent of the correctness of any theory whatever as to the cause of the failure of Stokes's law for small drops. It is entirely possible that a series

TABLE XI.

Negative Drop, No. 32.

Distance between cross hairs ..... = 1.003 centimeters
Temperature..... = 23.2° C.

	G Sec.	F Sec.	n	$e_0 \times 10^{10}$	$e_1 \times 10^{10}$
F = 8.5 / V = 8.57	....	8.7, 8.3, 8.5	123	622.40	
Charged without radium					
F = 28.70 / V = 8573	M 2.44	28.4, 28.7, ..., 28.7			
	" 2.46	28.4	104	524.25	5.040
	" 2.54	29.0			
	" 2.46	29.0			
	" 2.45	28.8			
	" 2.43	28.6			
Charge forced with radium					
G = 2.462 / F = 15.72 / V = 8568	" 2.44	15.7	111	558.78	5.034
	" 2.48	15.7			
		15.7			
	....	15.7			
	....	15.8			
Change forced with radium					
F = 59.1 / V = 8565	"	59.1	100	503.42	5.034
	" 2.50	59.1			
Change forced with radium					
F = 60.0 / V = 8563	"	59.8	100	503.23	5.032
	F 2.45	60.2			
Change forced with radium					
F = 81.5 / V = 8561	...	81.0	99	498.12	5.031
	...	82.1			
Change forced with radium					
F = 20.0 / V = 85.5	F 2.44	19.9	108	543.41	5.032
	" 2.50	20.1			
	" 2.42	20.0			

F = .4074 Mean e_1 (weighted) = **5.033**

F's mean G = 2.452 M's mean G = 2.467

Differences:	e_0	n	e	Prob. Error.
543.41 — 498.12 =	45.29 ÷	9 =	5.032	.5 per cent
504.24 — 49 .12 =	5.11 ÷	1 =	5 11	3.0 per cent
558 78 — 5 3.42 =	55.36 ÷	11 =	5.033	.5 per cent
558 78 — 524.25 =	31.53 ÷	7 =	4.94	3.0 per cent

Mean difference (weighted) **5.031**

TABLE XIII.

No.	Velocity cm.-sec.	Radius cm.	$e_1 \times 10^{10}$	Prob. Error.	$e \times 10^{10}$	Error.
5	.01085	967	5.480	.5	4.892	.20
6	.01107	959	5.496	.7	4.889	.26
7	.01164	.0001004	5.483	.4	4.903	.13
8	.01176	1046	5.483	.4	4.916	.28
9	.01193	1016	5.458	.8	4.891	.22
10	.01339	1084	5.448	.5	4.908	.10
11	.01415	1109	5.448	.4	4.921	.42
12	.01868	1281	5.349	.5	4.900	.03
13	.02613	1521	5.293	.5	4.910	.17
14	.03357	1730	5.257	.5	4.918	.34
15	.04265	1954	5.208	.5	4.913	.21
16	.05300	2205	5.143	.4	4.894	.30
17	.05534	2254	5.145	.5	4.895	.34
18	.06800	2481	5.143	.7	4.912	.21
19	.07270	2562	5.139	.5	4.913	.01
20	.08043	2815	5.102	.3	4.901	.01
21	.08622	2985	5.107	.4	4.915	.27
22	.1102	3166	5.065	.4	4.884	.36
23	.1219	3344	5.042	.5	4.892	.40
24	.1224	3329	5.096	.5	4.923	.44
25	.1207	3303	5.061	.5	4.894	.15
26	.15145	3712	5.027	.5	4.880	.44
27	.1644	3876	5.050	.3	4.903	.03

Final mean e = 4.9016

of experiments of this kind upon substances other than oil may lead to other values of A, but the value of e should in no way be affected thereby. It is of immense interest to know whether varying the mean free path by varying the pressure will affect the value of A in the way in which it ought according to Cunningham's theory and we shall soon be in a position to settle this point and to make a further communication upon it.

THE JAPANESE CAMPHOR INDUSTRY.

THE Osaka Mainichi states that the total production of camphor this year is estimated by the Monopoly Bureau at 4,062 tons, of which 3,510 tons will be produced in Formosa, and 522 tons in Shikoku and Kyushu. Of this quantity 2,321 tons is to be shipped to Europe, and 1,451 tons to America, the remainder being kept for the home market. The total demand for camphor in Europe and America is given as between 4,000 and 4,600 tons. No definite figures have yet been ascertained, but the actual demand is certainly not less than 4,350 tons. This being so, there is expected to be a deficit of some 580 tons in the supply shipped from Japan this year, and naturally the deficit may send up the price, while an impulse may also be given to the revival of the South China camphor industry and the manufacture of artificial camphor. The price of the camphor sold in Europe and America by the Monopoly Bureau is now only a fraction of the rate when the market reached the highest point. For this reason the revenue from the Camphor Monopoly has been seriously affected, and the government is trying to increase the price to a certain degree. The net profit of the Camphor Monopoly in Formosa last year was $700,000, while that in Japan proper did not exceed $50,000. The Osaka journal adds that the world's supply of camphor is almost entirely monopolized by Japan, and yet the revenue therefrom cannot be made an important item of the revenue of the Treasury. The total export of camphor from Formosa in 1909 was valued at $1,094,455, but the expenses of the Monopoly Office, including tobacco, salt, opium and camphor, amounted to as much as $1,893,305.

A METHOD OF FINDING THE MERIDIAN BY SHADOWS AND MECHANICALLY GRADUATING A SUN-DIAL.

By EDISON PETTIT.

IN all laboratory exercises in astronomy it is difficult to bring accuracy and simplicity together. Especially is this true in the two valuable exercises of establishing a meridian by shadows and of mechanically graduating a sun-dial. The methods here outlined are believed to accomplish this.

I. ESTABLISHING THE MERIDIAN.

At any time in the morning the sun will have a

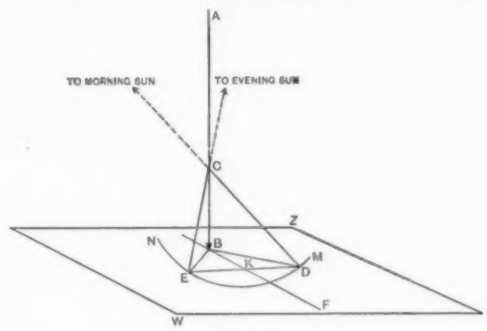


FIG. 1.

given altitude and make a certain angle with the meridian. At some time in the afternoon it will again have the same altitude, and will then make the same angle with the meridian, but on the other side of it.

Now whenever the sun has the same altitude in the sky, the shadow of a body cast on a level surface is always the same length; and, conversely, when the shadow is the same length the sun has the same altitude in the sky as before. Applying these principles we proceed as follows:

In a south window, level a table WZ, Fig. 1, and over the south edge hang a plumb line AB, having a bead C (a small shot split and mashed about the plumb line) attached so that it shall be a few inches above the table. Mark the position D of the shadow of the bead at any time in the morning, and with the point B (where the plumb bob touches the table) as a center and BD as a radius draw the arc MN. In the afternoon watch till the bead's shadow again touches this arc and mark its position E. The shadow is now the same

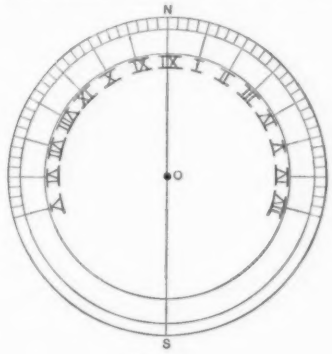


FIG. 2.

length as it was in the morning at D, and by the above principles the sun has the same altitude and the meridian is the bisector of the angle EBD. Draw EB, and BD, and bisect this angle. (For this it is necessary only to draw two arcs of equal radii, whose centers are at D and E and to connect their point of intersection with B.)

This line BF is the meridian, and if the work has been carefully done a high degree of accuracy may be attained.

II. GRADUATING THE SUN-DIAL.

For this purpose we require the construction of a simple piece of apparatus.

Divide a paper circle into twenty-four parts, and each of these parts into four parts as shown in Fig. 2. (It will be found convenient to have the circle about 3 inches in diameter.) Draw the diameter of the circle through one of the first divisions and number the divisions as shown in the figure. Glue this circle to one of the same size made of thin wood. Through the center of this circle pass a straight wire about a foot long. Support the wire perpendicular to the circle. To do this a block, B, may be glued to the back of the circle M and a hole a little smaller than the wire bored through it, as shown in the upper position of Fig. 3; then when the wire is inserted it will be held fast by its own friction. If a more permanent apparatus is desired, it may be constructed as shown in the lower figure. Solder a battery connector C to a metal plate

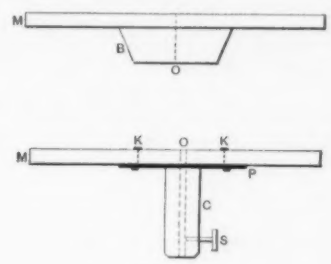


FIG. 3.

(tin or sheet brass) P, and attach this to the back of the circle C by means of two brads KK driven through from the graduated side of the circle and clinched tight on the metal plate. The thumb nut S may be used to adjust the circle on the rod, which passes through the hole O.

On the paper or other surface to be graduated, KL, Fig. 4, draw a straight line, NS, down the middle to represent the meridian. Near one end of the line at A erect a perpendicular $A6$, to represent the six-hour line. Place a sharpened end of the wire BA, so that it will make an angle BAN with the board equal to the latitude of the place for which the dial is being constructed, and likewise be in the plane of the meridian NS.

To adjust the wire at the proper angle and direction, level the board KL, and suspend a plumb line DF from the wire AB and move the wire so that the bob shall hang over the meridian NS, then set AB at the proper angle with a protractor. When this is done the wire should be held firmly in place by means of a laboratory support placed at some point near the end B of the wire. Now tie a thread on the wire at some convenient

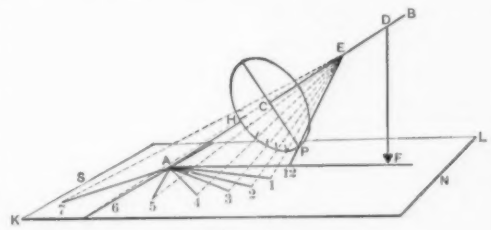


FIG. 4.

point as E which should be near the end B, and stretch it fairly tight to the meridian, just touching the circle C as at P.

Bring the XII mark on the circle to coincide with the thread. Then bring the thread to the 6-hour line at 6, and it should touch the circle at the VI-hour mark H. If it does not, the position of the axis must be changed to one side so that it will. When the circle is properly adjusted the thread will touch the VI-hour mark on the circle when held on the 6-hour line, and the XII-hour mark when held to the meridian and the angle BAF will be equal to the latitude of the place. Now bring the thread into coincidence with each of the other graduations on the circle and each time mark the place, 1, 2, 3, etc., where it strikes the paper, KL, together with a number corresponding with the number on the circle. For places in the United States it will be only necessary to graduate the dial for hours between 5 A. M. and 7 P. M.

Finally, connect all the points so found with the point A, and extend the lines to the edge of the paper.

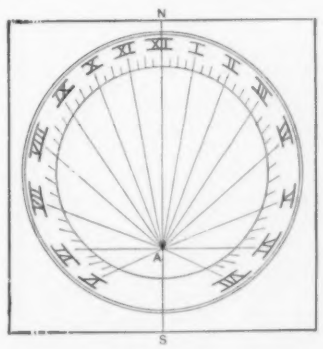


FIG. 5.

The graduations may be finished off as shown in Fig. 5. Now remove the circle from the wire, and drive the wire in at the point A, being careful to have it in the same position it was throughout the process, that is to

say, making an angle with the dial equal to the latitude of the place and pointing in the direction of the meridian line.

If a vertical dial is desired the process of graduation is exactly the same except that the angle between the board and the wire must be equal to the complement of the latitude of the place throughout the process, and it is only necessary to graduate the dial for hours from 6 A. M. to 6 P. M. for any latitude.

When the dial is complete it is only necessary to set it so that the meridian mark is in the meridian of the place. If it be a horizontal dial it must be level, if a vertical dial it must stand in the plane of the prime vertical, as on the south wall of a building with the graduations down. When properly set up the shadow of the wire on the graduations will mark the apparent solar time, from which, by knowing the longitude and the equation of time, the standard time may be found. —School Science and Mathematics.

SORCERERS PAST AND PRESENT.

By G. LE NOTRE.

IN the island of Reunion eight sorcerers were recently condemned to death for killing three French colonists in obedience to the command of the devil, but their condemnation did not prevent other sorcerers going to a cemetery, three days afterward, and disinterring the body of a child for use in their sorceries. The French newspapers very recently printed a story of a Spanish peasant who, at the direction of a sorcerer, cut the throat of a nine-year-old boy, drank the child's blood and employed its entrails as a cataplasm, for the cure of some ailment.

These incidents, which are worthy of the Middle Ages, form but a small part of the evidence that could be cited to prove that, even in this enlightened age of railways, telephones, aeroplanes and universal compulsory education, certain superstitious beliefs persist as obstinately as if they were innate in the human mind, or were inspired by the devil in person, as our forefathers believed.

In olden times the devil was the convenient and all-sufficient explanation of these phenomena of morbid psychology, satisfactory alike to judges, criminals, victims and the general public.

An old book which treats of trials for sorcery in the reign of Louis XIV. contains many cases similar to the modern instances cited above, in which the learned magistrates did not hesitate to admit the direct intervention of the devil, and—which is still more remarkable—the culprits braved the penalty of death by confessing that they owed their powers of sorcery to their personal relations with the father of evil.

In a case which was tried in Lorraine in 1608, and the court records of which are still in existence, the accused was a farmer's widow, named Jehannon le Regnard. She asserted that she was an honest woman and a good Christian, and had never been guilty of sorcery. She was shown the rack and other instruments of torture, but she continued to assert her innocence, even when the executioner seized her and advised her to save herself from the torture by confessing, for he knew well that she was a skillful sorceress. But when she was placed on the rack and the cords attached to her hands and feet were pulled, she quickly begged for mercy and consented to confess everything.

She said that, seventeen or eighteen years previously, when she was cutting wood in the forest, she was accosted by a man clad in red, who expressed compassion for her poverty and promised that, if she would accept him as her master and would deny God, he would make her rich and happy, and would give her the means to revenge herself upon her neighbors, who showed her no pity and jeered at her wretchedness. Seduced by the fine words of the stranger, she had consented to become his slave and had denied God. The red-garbed man then clapped her on the forehead, told her that his name was Persin, and filled her lap with silver, but when she had regained her home the supposed coins proved to be oak leaves. Persin had also given her a white powder for curing disease and a black powder for causing death. She gave some of the black powder to her cow and her pig, and both animals died in a few hours.

Jehennon also said that Persin had taken her to the witches' sabbath. He carried her on his shoulder to a place in the forest where there was a great fire and a banquet was being prepared. Asked what she had eaten at this diabolical feast, she replied that she had eaten unsalted meat. The guests, who were very numerous, sat on the ground, and Persin and another devil presided. After the banquet the guests danced, to the music of violins. Jehennon gave the names of several women of her village whom she had seen at the sabbath. She also said that on that night she had learned the art of making hail, by stirring water with a stick, and that in this way she had caused a violent hailstorm that had devastated all the surrounding country. She attended the witches' sabbath many times, always on a Thursday night, and was carried thither by the wind, as swiftly as a bird could fly. In conclusion, she confessed all the poisonings, acts of vengeance and other sorceries which she had committed.

This wretched woman was, of course, burned at the stake. The questions put to her as they are recorded, suggest that she was innocent and that her confession was inspired solely by fear of torture. But this idea is quickly dispelled by reading the reports of other cases. In 1630, for example, a woman confessed that she frequented the witches' sabbath, and accused her brother of visiting it also. The man, when put to the torture, told of the same things that Jehennon had described. In 1609 another person accused of sorcery confessed that he had yielded to the solicitations of a man, clad in green or black, who had given him pieces of gold which changed to manure in his pocket. In 1611 a fourth suspect described the witches' sabbath in detail, and said that he had gone thither in the form of a huge rat and that the guests had danced back to back. In Lorraine alone between 1558 and 1661, more than 800 persons were tried for sorcery, and every one of them told the same story. Every one had entered the service of Persin or his brother devil Napnel, and had received black and white powders, with which he could kill or cure at will. All had visited the witches' sabbath, and had witnessed scenes differing only in detail. One had seen a black hen, another had been carried to the sabbath on the horns of Persin, a third had become acquainted with three additional devils called Jolibois, Sante-Buisson, and Verdelet. Every one had been struck by his master and bore, either on his head or on his back, the mark of the devil's claw, in the form of a black dot, in which the executioner plunged a long pin without eliciting any symptom of pain.

If the confessions had been evoked solely by the fear of torture they would naturally have varied greatly, for each prisoner would have uttered the first thing that came into his head. What is the explanation of this astounding similarity of hundreds of confessions, extending over more than a century?

During this period the Abbot Dominique Cordet was so deeply impressed by the similarity of these confessions that he undertook the study of sorcery, in the interest of religion. He became convinced that the crime of sorcery, despite its gravity, did not deserve the punishment of death by fire and, as he prided himself on his ability to detect at a glance any person who had fallen under the influence of Persin, he contented himself with exorcising the demon. It is almost needless to add that this clemency did not find favor with the magistrates and that the good abbot, like so many other men, was burned at the stake for meddling with things that did not concern him.

Torture is, happily, abolished forever and by universal consent, but it is unfortunate that we possess no sure means for extorting full confessions from criminals like the ghouls of Reunion and the Spanish vampire. Perhaps if such confessions could be obtained we should find that nothing has changed, and that the instigator of the crime is always a man clad in red or black, who gives his slaves coins that change into leaves, and presides, every Thursday night, at a witches' sabbath, where the guests eat unsalted meat and dance back to back.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Le Monde Illustré.

THE ELECTRICITY OF RAIN AND SNOW.

DR. KAEHLER has recently published the results of the registration of the electricity of rain and snow for the year 1908, according to the measurements made by the Royal Meteorological Institute of Prussia. These measurements are made by means of a collector for the rain or snow, connected with a registering electrometer, which makes a continuous record of the sign and magnitude of the electric charge of the water precipitated. The sheet-metal vessel which serves as a collector must be well insulated, and also protected from the action of the electrical field of force due to the earth. The insulation is accomplished by insulators of amber and desiccation by sodium. The inductive action of the earth is guarded against by placing over the vessel and over the roof of the little building which shelters it sheets of metal and wire netting connected with the earth. There is an aperture in the roof directly above the collecting vessel. The collector is connected with a registering Benndorf electrometer. This instrument consists of a needle or suspended plate of metal, capable of rotation in the center of a group of four insulated quadrants, which are alternately connected with the positive and negative poles of a galvanic battery of several hundred volts. If the needle receives from the water collector an electric charge of a certain sign, it is attracted toward the quadrants whose potential is of the opposite sign. The angle through which the needle turns is proportional to the potential of the needle and collector; and when the capacity of the collector and the electrometer is known, the quantity of the electric charge can be calculated. A pointer attached to the needle moves over a moving strip of paper, upon which it is pressed at intervals of two minutes by a rotating cam, thus making a record of the deflection. The cam simultaneously discharges the needle.

The most interesting of the results concern the magnitude and sign of the electric charge of the collected water. If we represent the charge as a positive or negative current brought to the earth by the precipitated water, we find that in general the strength of this current is very small. In an ordinary rain shower or snowfall, the current ranges from 10^{-16} to 10^{-15} ampere for each square centimeter of the surface of the earth. Even in heavy rains and thunder storms the value of the current seldom exceeds 10^{-13} ampere per square centimeter. The sign of the current or charge is in the main positive. Of the one hundred rainfalls which are recorded, fifty-five showed exclusively positive charges, while only ten, and those of short duration, showed exclusively negative charges. In the other cases the sign varied during the rainfall. In snowfalls no preponderance of either sign was exhibited. When rain and snow fall together, there is usually an excess of positive charge. The same is true in the case of thunder storms and squalls.

The total excess of positive electricity received per square centimeter of the earth's surface in six months at Potsdam is equal to a current of the value of 1.7×10^{-13} ampere, flowing during one hour from the air to the earth. The course of the fall of electric potential is usually in the opposite direction to that of the quantity of deposit. These measurements afford proof of the fact that the observed negative charge of the earth cannot be caused by the assumed negative charge of rain and snow.—Prometheus.

Modern Gas Engines and Producer Gas Plants

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